This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Geological Survey water-supply paper

Geological Survey (U.S.)

HARVARD UNIVERSITY

LIBRARY OF THE
MINERALOGICAL
LABORATORY

UNIVERSITY MUSEUM

Water-Supply and Irrigation Paper No. 214 Series P, Hydrographic Progress Reports, 68

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

SURFACE WATER SUPPLY
OF
THE NORTH PACIFIC COAST DRAINAGE, 1906

J. C. STEVENS, ROBERT FOLLANSBEE, and E. C. LA RUE
DISTRICT HYDROGRAPHERS

WORK IN OREGON DONE IN COOPERATION WITH THE STATE ENGINEER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1907

CONTENTS.

Page.
Introduction 1
  Scope of work 1
  Definitions 3
  Explanation and use of tables 4
  Convenient equivalents 6
  Field methods of measuring stream flow 7
  Office methods of computing run-off 13
  Cooperation and acknowledgments 16
Columbia River drainage 17
  Columbia River proper 17
    Description of basin 17
    Columbia River at Pasco, Wash 18
    Miscellaneous measurements 19
  Clark Fork drainage basin 20
    Description of basin 20
    Clark Fork near Grantsdale, Mont 20
    Clark Fork at Missoula, Mont 22
    Stillwater River near Kalispell, Mont 23
    Whitefish River near Kalispell, Mont 25
    Crow Creek near Ronan, Mont 25
    Mission Creek near St. Ignatius, Mont 27
    Post Creek near St. Ignatius, Mont 28
    Jocko River at Ravalli, Mont 29
    Miscellaneous measurements 30
  Spokane River drainage basin 30
    Description of basin 30
    Spokane River at Spokane, Wash 31
    Miscellaneous measurements 32
  Okanogan River basin 32
    Description of basin 32
    Salmon Creek near Malott, Wash 33
    Johnson Creek near Riverside, Wash 33
  Methow River drainage basin 36
    Methow River at Pateros, Wash 36
  Chelan River drainage basin 37
    Chelan River at Chelan, Wash 37
  Wenatchee River drainage basin 39
    Wenatchee River at Cashmere, Wash 39
  Yakima River drainage basin 41
    Description of basin 41
    Yakima River near Martin, Wash 41
    Yakima River at Clealum, Wash 43

Columbia River drainage—Continued. Page.

Yakima River drainage basin—Continued.

Yakima River at Umtanum, Wash........ 44
Yakima River near Yakima, Wash........ 45
Yakima River at Prosser, Wash........ 47
Yakima River at Kiona, Wash........ 49
Yakima River near Richland, Wash........ 51
Lake Keechelus near Martin, Wash........ 52
Kachess Lake near Easton, Wash........ 50
Kachess River near Easton, Wash........ 53
Clealum River near Roslyn, Wash........ 55
Naches River near Nile, Wash........ 56
Naches River near North Yakima, Wash........ 58
Bumping River near Nile, Wash........ 60
Tieton River at headworks near Natchez, Wash........ 61
Tieton River near Naches, Wash........ 62
Low-water measurements of tributaries of Lake Kachess........ 64
Low-water measurements of tributaries of Lake Keechelus........ 65
Miscellaneous measurements........ 65
Canals in Yakima Valley........ 67
  Sunnyside canal near Yakima, Wash........ 67
  New Reservation canal near Yakima, Wash........ 68
  Old Reservation canal near Wapato, Wash........ 68
  Miscellaneous measurements of canals........ 70
Snake River drainage basin........ 71
  Description of basin........ 71
  North Fork of Snake River near Ora, Idaho........ 72
  Snake River near Minidoka, Idaho........ 73
  Snake River between Milner dam and Shoshone Falls during November, 1906........ 75
  Snake River at Neeley, Idaho........ 76
  Fall River at Fremont, Idaho........ 76
  Teton River near St. Anthony, Idaho........ 78
  South Fork of Snake River at Moran, Idaho........ 79
  South Fork of Snake River near Lyon, Idaho........ 81
  Buffalo River near Elk, Wyo........ 82
  Pacific Creek near Moran, Wyo........ 83
  Blackfoot River near Presto, Idaho........ 84
  Big Lost River near Mackay, Idaho........ 85
  Big Lost River near Chilly, Idaho........ 87
  Big Wood River near Shoshone, Idaho........ 88
  Succor Creek near Homedale, Idaho........ 89
  Owyhee River near Owyhee, Oreg........ 91
  Boise River near Highland, Idaho........ 93
  Seepage investigations on Boise River........ 94
  Payette River near Horeshoe Bend, Idaho........ 97
  Malheur River at McLaughlin's bridge, near Vale, Oreg........ 99
  Malheur River at Vale, Oreg........ 101
  Middle Fork of Malheur River at Riverside, Oreg........ 102
  Bully Creek above Vale, Oreg........ 103
  Bully Creek at Vale, Oreg........ 105
  Willow Creek near Malheur, Oreg........ 105
  Willow Creek near Dell, Oreg........ 106
  Powder River at Salisbury, Oreg........ 108

Columbia River drainage—Continued. Page.

Snake River drainage basin—Continued.

Grande Ronde River at Hilgard, Oreg.................................. 109
Grande Ronde River at Elgin, Oreg.................................. 110
Grande Ronde River at Zindel, Wash.................................. 111
Catherine Creek near Union, Oreg.................................. 112
Wallowa River at Joseph, Oreg.................................. 113
Wallowa River near Wallowa, Oreg.................................. 115
Wallowa River near Elgin, Oreg.................................. 116
Asotin Creek near Asotin, Wash.................................. 118
Palouse River at Hooper, Wash.................................. 119
Miscellaneous measurements in Snake River basin.................. 121
Walla Walla River drainage basin.................................. 122
Description of basin.................................. 122
Walla Walla River near Milton, Oreg.................................. 123
South Fork of Walla Walla River near Milton, Oreg.................. 124
Miscellaneous measurements.................................. 126
Umatilla River drainage basin.................................. 126
Description of basin.................................. 126
Umatilla River at Gibbon, Oreg.................................. 126
Umatilla River at Yoakum, Oreg.................................. 128
Umatilla River at Umatilla, Oreg.................................. 129
Miscellaneous measurements.................................. 131
Canals in Umatilla River Valley, Oreg.................................. 132
Willow Creek drainage basin.................................. 134
Description of basin.................................. 134
Willow Creek near Arlington, Oreg.................................. 134
John Day River drainage basin.................................. 135
John Day River at McDonald, Oreg.................................. 135
Miscellaneous measurements.................................. 137
Deschutes River drainage basin.................................. 138
Description of basin.................................. 138
Deschutes River near Lava, Oreg.................................. 138
Deschutes River at West's Ranch near Lava, Oreg.................. 140
Deschutes River at Bend, Oreg.................................. 141
Deschutes River near Biggs, Oreg.................................. 141
East Fork of Deschutes River at Odell, Oreg.................. 143
West Fork of Deschutes River near Lava, Oreg.................. 144
Central Oregon and Pilot Butte canals near Bend, Oreg.................. 146
Tumalo Creek near Laidlaw, Oreg.................................. 148
Tumalo Creek near Bend, Oreg.................................. 149
Wymer Canal near Laidlaw, Oreg.................................. 150
Columbia Southern Canal near Laidlaw, Oreg.................. 151
Squaw Creek near Sisters, Oreg.................................. 152
Miscellaneous measurements.................................. 154
Hood River drainage basin.................................. 154
Hood River at Winans, Oreg.................................. 154
Willamette River drainage basin.................................. 156
Description of basin.................................. 156
Willamette River at Albany, Oreg.................................. 156
Middle Fork of Willamette River at Jasper, Oreg.................. 158
Coast Fork of Willamette River near Goshen, Oreg.................. 160
McKenzie River near Springfield, Oreg.................................. 162
North Fork of Santiam River at Mehama, Oreg.................. 164

Columbia River drainage—Continued.

Page.
Willamette River drainage basin—Continued.
South Fork of Santiam River at Waterloo, Oreg........................ 166
Luckiamute River near Suver, Oreg........................ 168
Molalla River near Molalla, Oreg........................ 170
South Fork of Yamhill River at Sheridan, Oreg........................ 172
Clackamas River near Barton, Oreg........................ 174
Miscellaneous measurements........................ 176
Puget Sound drainage........................ 178
Description........................ 178
Snohomish River drainage basin........................ 178
Snoqualmie River near Snoqualmie Falls, Wash........................ 178
White River drainage basin........................ 179
Cedar River near Ravensdale, Wash........................ 179
Miscellaneous measurements in Puget Sound basin........................ 181
Northern Pacific Ocean drainage........................ 181
Description........................ 181
Siletz River basin........................ 182
Siletz River at Siletz, Oreg........................ 182
Umpqua River drainage basin........................ 183
Umpqua River at Elkton, Oreg........................ 183
North Fork of Umpqua River near Oakcreek, Oreg........................ 184
South Fork of Umpqua River near Brockway, Oreg........................ 186
Illinois River drainage basin........................ 188
Rogue River near Tolo, Oreg........................ 189
Rogue River near Galice, Oreg........................ 190
Nehalem River drainage basin........................ 191
Nehalem River at Fishhawk, Oreg........................ 191
Miscellaneous measurements in Northern Pacific Ocean drainage........................ 192

ILLUSTRATIONS.

Page.
PLATE I. Map of United States showing location of principal river stations maintained during 1906........................ 2
II. *A*, Current-meter rating station, Los Angeles, Cal.; *B*, Price current meters........................ 10
III. *A*, Cable station, Yakima River near Union Gap, near Yakima, Wash.; *B*, Discharge measurement by wading........................ 44
FIG. 1. Cable station showing section of river, car, gage, etc........................ 11
2. Typical discharge, area, and mean-velocity curves........................ 15

SURFACE WATER SUPPLY OF THE NORTH PACIFIC COAST DRAINAGE, 1906.[a]

J. C. STEVENS, ROBERT FOLLANSBEE, and E. C. LA RUE,

District Hydrographers.[b]

INTRODUCTION.

SCOPE OF WORK.

The water supply of the United States is of more importance to the life and pursuits of the people than is any other natural resource. In the arid States the limit of agricultural development is determined by the amount of water available for irrigation, while in all parts of the country the increase in the population of cities and towns makes necessary additional water supplies for domestic and industrial uses, in procuring which both the quantity and the quality of the water that may be obtained must be considered. The location of manufacturing plants may depend largely on the water-power facilities and on the character of the water. The notable advances made in the electric transmission of power have led to the utilization of water powers for the operation of manufacturing establishments, railroads, and municipal lighting plants, many of which are at some distance from the places at which the power is developed.

The intelligent establishment and maintenance of enterprises or industries that depend on the use of water demands a thorough knowledge of the flow of the streams and an understanding of the conditions affecting that flow. This knowledge should be based on data showing both the total flow and the distribution of the flow throughout the year, in order that normal fluctuations may be provided for. As the flow of a stream is variable from year to year estimates of future flow can be made only from a study of observations covering several years. The rapid increase in the development of the water resources of the United States has caused a great demand by engineers for information in regard to the flow of streams, as it is now generally realized that the failure of many large power, irrigation, and other projects has been due to the fact that the plans were made without sufficient trustworthy information in respect to the water supply.

---

[a] The report contains information similar to that published in previous years under the title "Report of Progress of Stream Measurements."

[b] The data presented in this paper have been collected as follows:

Columbia River drainage in Oregon and Washington, and Puget Sound and Pacific Coast drainages north of the Oregon-California State line, by J. C. Stevens, district hydrographer, assisted by R. M. Hall, Ivan Landes, W. C. Muldrow, and H. D. McGlashan; in cooperation in Oregon with John H. Lewis, State engineer, assisted by L. R. Allen, Ivan E. Oakes, and Percy A. Cupper.

Clark Fork drainage by Robert Follansbee, district hydrographer.

Snake River drainage in Idaho and Wyoming by E. C. La Rue, district hydrographer.

The data have been prepared for publication under the direction of John C. Hoyt by R. H. Bolster, Robert Follansbee, F. F. Henshaw, J. E. Stewart, and H. D. Padgett.

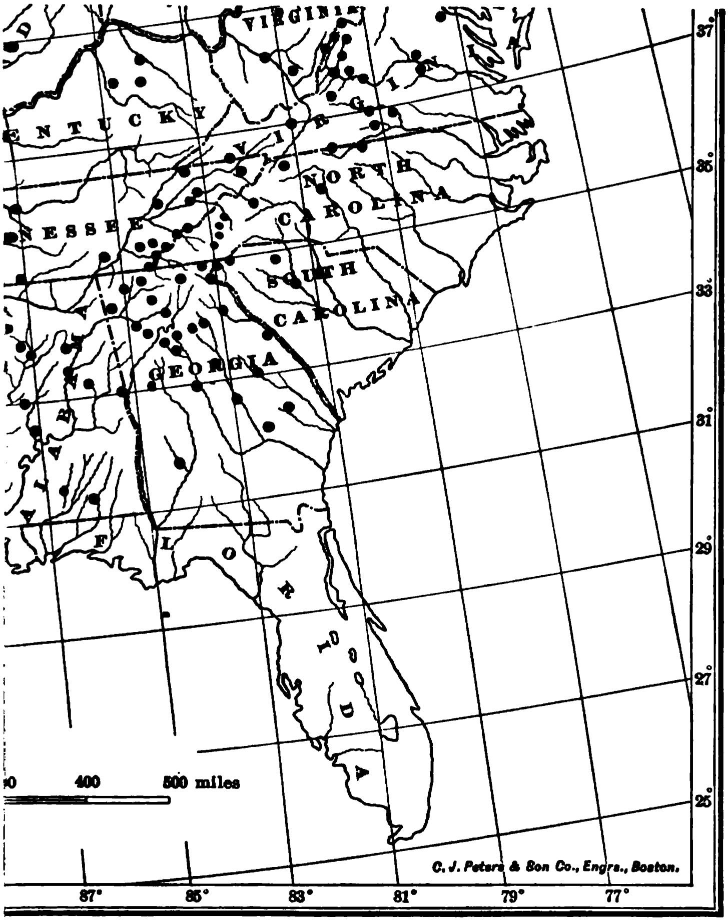
Owing to the broad scope of these hydrographic investigations and the length of time they should cover in order that the records may be of greatest value, it is, in general, impossible for private individuals to collect the necessary data, and as many of the streams traverse more than one State this work does not properly fall within the province of the State authorities. The United States Geological Survey has therefore, by means of specific appropriations by Congress, for several years systematically made records of stream flow, with the view of ultimately determining all the important features governing the flow of the principal streams of the country. In carrying out this plan stations are established on the streams and maintained for a period long enough to show their regimen or general behavior. When a record that is sufficient for this purpose has been obtained for any stream the work on that stream is discontinued. The order in which the streams are measured is determined by the degree of their importance.

During 1906 the regimen of flow was studied at about 700 stations distributed along the various rivers throughout the United States, as shown on Pl. I. In addition to these records data in regard to precipitation, evaporation, water power, and river profiles were obtained in many sections of the country.

These data have been assembled by drainage areas, and are published in a series of fourteen Water-Supply and Irrigation Papers, Nos. 201 to 214, inclusive, each of which pertains to the surface water resources of a group of adjacent areas. In these papers are embodied not only the data collected in the field, but also the results of computations based on these data, and other information that has a direct bearing on the subject, such as descriptions of basins and the streams draining them, utility of the water resources, etc. The list follows:

Water-Supply and Irrigation Papers on surface water supply, 1906.

201. Surface water supply of New England, 1906. (Atlantic coast of New England drainage.)
202. Surface water supply of the Hudson, Passaic, Raritan, and Delaware river drainages, 1906.
203. Surface water supply of the Middle Atlantic States, 1906. (Susquehanna, Gunpowder, Patapsco, Potomac, James, Roanoke, and Yadkin river drainages.)


VIRGINIA
KENTUCKY
VIRGINIA
NORTH CAROLINA
TENNESSEE
SOUTH CAROLINA
GEORGIA
ALABAMA
FLORIDA
37°
35°
33°
31°
29°
27°
25°
87°
85°
83°
81°
79°
77°
400
500 miles
C. J. Peters & Son Co., Engrs., Boston.

URING 1906.

204. Surface water supply of the Southern Atlantic and Eastern Gulf States, 1906. (Santee, Savannah, Ogeechee, and Altamaha rivers, and eastern Gulf of Mexico drainages.)
205. Surface water supply of the Ohio and lower eastern Mississippi river drainages, 1906.
206. Surface water supply of the Great Lakes and St. Lawrence River drainages, 1906.
207. Surface water supply of Hudson Bay and upper Mississippi River drainages, 1906.
208. Surface water supply of the Missouri River drainage, 1906.
209. Surface water supply of the lower western Mississippi River drainage, 1906.
210. Surface water supply of the western Gulf of Mexico and Rio Grande drainages, 1906.
211. Surface water supply of the Colorado River drainage above Yuma, 1906.
212. Surface water supply of the Great Basin drainage, 1906.
213. Surface water supply of California, 1906. (The Great Basin and Pacific Ocean drainage in California, and Colorado River drainage below Yuma.)
214. Surface water supply of the North Pacific Coast drainage, 1906.

The records at most of the stations discussed in these reports extend over a series of years. An index of the reports containing such records up to and including 1903 has been published in Water-Supply Paper No. 119. The following table gives, by years and primary drainage basins, the numbers of the papers on the surface water supply, published from 1901 to 1906.

Number of Water-Supply Papers containing results of stream measurements, 1901–1906.[a]

	1901.	1902.	1903.	1904.	1905.	1906.
Atlantic coast of New England drainage	65 75	82	97	124	165	201
Hudson, Passaic, Raritan, and Delaware river drainages	65 75	82	97	125	166	202
Susquehanna, Gunpowder, Patapsco, Potomac, James, Roanoke, and Yadkin river drainages	65 75	82 83	97 98	126	167	203
Santee, Savannah, Ogeechee, and Altamaha rivers, and eastern Gulf of Mexico drainages	65 75	83	98	127	168	204
Ohio and lower eastern Mississippi river drainages	65 75	83	98	128	169	205
Great Lakes and St. Lawrence River drainages	65	83	97	129	170	206
Hudson Bay and upper eastern and western Mississippi River drainages	65 66 75	83 84 85	98 99 100	128 130	171	207
Missouri River drainage	66 75	84	99	130 131	172	208
Meramec, Arkansas, Red, and lower western Mississippi river drainages	66 75	84	99	131	173	209
Western Gulf of Mexico and Rio Grande drainages	66 75	84	99	132	174	210
Colorado River drainage above Yuma	66 75	85	100	133	175	211
The Great Basin drainage	66 75	85	100	133	176	212
The Great Basin and Pacific Ocean drainages in California, and Colorado River drainage below Yuma	66 75	85	100	134	177	213
North Pacific Coast drainage	66 75	85	100	135	178	214

[a] Reports containing data for years prior to 1901 are noted in the series list at the end of this paper.

DEFINITIONS.

The volume of water flowing in a stream—the "run-off" or "discharge"—is expressed in various terms, each of which has become associated with a certain class of work. These terms may be divided into two groups: (1) Those which represent a rate of flow, as second-feet, gallons per minute, miner's inches, and run-off in second-feet per square mile; and (2) those which represent the actual quantity of water, as run-off in depth in inches and acre-feet. They may be defined as follows:

"Second-foot" is an abbreviation for cubic foot per second and is the quantity of water flowing in a stream 1 foot wide, 1 foot deep, at a rate of 1 foot per second. It is generally used as a fundamental unit from which others are computed.

"Gallons per minute" is generally used in connection with pumping and city water supply.

The "miner's inch" is the quantity of water that passes through an orifice 1 inch square under a head which varies locally. It has been commonly used by miners and irrigators throughout the West, and is defined by statute in each State in which it is used.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly, both as regards time and area.

"Run-off in inches" is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is usually expressed in depth in inches.

"Acre-foot" is equivalent to 43,560 cubic feet, and is the quantity required to cover an acre to the depth of 1 foot. It is commonly used in connection with storage for irrigation work. There is a convenient relation between the second-foot and the acre-foot: One second-foot flowing for twenty-four hours will deliver 86,400 cubic feet, or approximately 2 acre-feet.

EXPLANATION AND USE OF TABLES.

For each regular gaging station are given, as far as available, the following data:

1. Description of station.
2. List of discharge measurements.
3. Gage-height table.
4. Rating table.
5. Table of monthly and yearly discharges and run-off.
6. Tables showing discharge and horsepower and the number of days during the year when the same are available.

The descriptions of stations give such general information about the locality and equipment as would enable the reader to find and use the station, and they also give, as far as possible, a complete history of all the changes that have occurred since the establishment of the station that would be factors in using the data collected.

The discharge-measurement table gives the results of the discharge measurements made during the year, including the date, the name of the hydrographer, the width and area of cross section, the gage height, and the discharge in second-feet.

The table of daily gage heights gives the daily fluctuations of the surface of the river as found from the mean of the gage heights taken each day. The gage height given in the table represents the elevation of the surface of the water above the zero of the gage. At most stations the gage is read in the morning and in the evening.

The discharge measurements and gage heights are the base data from which the other tables are computed. In cases of extensive development it is expected that engineers will use these original data in making their calculations, as the computations made by the Survey are based on the data available at the time they are made and should be reviewed, and, if necessary, revised when additional data are available.

The rating table gives the discharge in second-feet corresponding to various stages of the river as given by the gage heights. It is published to enable engineers to determine the daily discharge, in case this information is desired.

In the table of monthly discharge, the column headed "Maximum" gives the mean flow for the day when the mean gage height was highest, and it is the flow as given in the rating table for that mean gage height. As the gage height is the mean for the day, there might have been short periods when the water was higher and the corresponding discharge larger than given in this column. Likewise, in the column of "Minimum," the quantity given is the mean flow for the day when the mean gage height was lowest. The column headed "Mean" is the average flow for each second during the month. Upon this the computations for the remaining columns, which are defined on page 4, are based.

The values in the table of monthly discharge are intended to give only a general idea of the conditions of flow at the station, and it is not expected that they will be used for other than preliminary estimates.

In most work where data in regard to flow are used the regimen of flow is of primary importance. Therefore, for the principal stations, tables have been prepared showing the horsepower that can be developed at various rates of flow, and the length of time that these rates of flow and the corresponding horsepower are available.

These tables have been prepared on a basis of 80 per cent efficiency on the turbines, and the horsepower per foot of fall is given in order that the reader can determine the horsepower for any fall.

In the computations, sufficient significant figures have been used so that the percentage of error in the tables will not in general exceed 1 per cent. Therefore, most of the values in the tables are given to only three significant figures. In making the various computations Thatcher's slide rule, Crelle's tables, and computation machines have been generally used.

In order to give engineers an idea of the relative value of the various data, notes in regard to accuracy are given as far as possible. This accuracy depends on the general local conditions at the gaging stations and the amount of data collected. Every effort possible is made to so locate the stations that the data collected will give a high degree of accuracy. This is not always possible but it is considered better to publish rough values with explanatory notes rather than no data.

In the accuracy notes the following terms have been used indicating the probable accuracy, in per cent, of the mean monthly flow. As these values are mean values, the error in the value for the flow of any individual day may be much larger.

Excellent indicates that the mean monthly flow is probably accurate to within 5 per cent; good, to within 10 per cent; fair, to within 15 per cent; approximate, to within 25 per cent.

CONVENIENT EQUIVALENTS.

Following is a table of convenient equivalents for use in hydraulic computations:

1 second-foot equals 40 California miner's inches (law of March 23, 1901).

1 second-foot equals 38.4 Colorado miner's inches.

1 second-foot equals 40 Arizona miner's inches.

1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,272 gallons for one day.

1 second-foot equals 6.23 British imperial gallons per second.

1 second-foot for one year covers 1 square mile 1.131 feet deep, 13.572 inches deep.

1 second-foot for one year equals 31,536,000 cubic feet.

1 second-foot equals about 1 acre-inch per hour.

1 second-foot for one day covers 1 square mile 0.03719 inch deep.

1 second-foot for one 28-day month covers 1 square mile 1.041 inches deep.

1 second-foot for one 29-day month covers 1 square mile 1.079 inches deep.

1 second-foot for one 30-day month covers 1 square mile 1.116 inches deep.

1 second-foot for one 31-day month covers 1 square mile 1.153 inches deep.

1 second-foot for one day equals 1.983 acre-feet.

1 second-foot for one 28-day month equals 55.54 acre-feet.

1 second-foot for one 29-day month equals 57.52 acre-feet.

1 second-foot for one 30-day month equals 59.50 acre-feet.

1 second-foot for one 31-day month equals 61.49 acre-feet.

100 California miner's inches equal 18.7 United States gallons per second.
100 California miner's inches equal 96.0 Colorado miner's inches.
100 California miner's inches for one day equal 4.96 acre-feet.
100 Colorado miner's inches equal 2.60 second-feet.
100 Colorado miner's inches equal 19.5 United States gallons per second.
100 Colorado miner's inches equal 104 California miner's inches.
100 Colorado miner's inches for one day equal 5.17 acre-feet.
100 United States gallons per minute equal 0.223 second-foot.
100 United States gallons per minute for one day equal 0.442 acre-foot.
1,000,000 United States gallons per day equal 1.55 second-feet.
1,000,000 United States gallons equal 3.07 acre-feet.
1,000,000 cubic feet equal 22.95 acre-feet.
1 acre-foot equals 325,850 gallons.
1 inch deep on 1 square mile equals 2,323,200 cubic feet.
1 inch deep on 1 square mile equals 0.0737 second-foot per year.
1 foot equals 0.3048 meter.
1 mile equals 1.60935 kilometers.
1 mile equals 5.280 feet.
1 acre equals 0.4047 hectare.
1 acre equals 43,560 square feet.
1 acre equals 209 feet square, nearly.
1 square mile equals 2.59 square kilometers.
1 cubic foot equals 0.0283 cubic meter.
1 cubic foot equals 7.48 gallons.
1 cubic foot of water weighs 62.5 pounds.
1 cubic meter per minute equals 0.5886 second-foot.
1 horsepower equals 550 foot-pounds per second.
1 horsepower equals 76.0 kilogram-meters per second.
1 horsepower equals 746 watts.
1 horsepower equals 1 second-foot falling 8.80 feet.
1⅓ horsepower equal about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Sec.-ft.} \times \text{fall in feet}}{11}$ = net horsepower on water wheel, realizing 80 per cent of theoretical power.

FIELD METHODS OF MEASURING STREAM FLOW.

The methods used in collecting these data and in preparing them for publication are given in detail in Water-Supply Papers No. 94 (Hydrographic Manual, U. S. Geol. Survey) and No. 95 (Accuracy of Stream Measurements). In order that those who use this report may readily become acquainted with the general methods employed, the following brief descriptions are given:

Streams may be divided, with respect to their physical conditions, into three classes—(1) those with permanent beds; (2) those with beds which change only during extreme low or high water; (3) those with constantly shifting beds. In determining the daily flow special methods are necessary for each class. The data on which the determinations are based and the methods of collecting them are, however, in general the same.

There are three distinct methods of determining the flow of open-channel streams—(1) by measurements of slope and cross section and the use of Chezy's and Kutter's formulas; (2) by means of a weir; (3) by measurements of the velocity of the current and the area of the cross section. The method chosen for any case depends on the local physical conditions, the degree of accuracy desired, the funds available, and the length of time that the record is to be continued.

Slope method.—Much information has been collected relative to the coefficients to be used in the Chezy formula, $v=c\sqrt{R\,s}$. This has been utilized by Kutter, both in developing his formula for c and in determining the values of the coefficient n which appears therein. The results obtained by the slope method are in general only roughly approximate, owing to the difficulty in obtaining accurate data and the uncertainty of the value for n to be used in Kutter's formula. The most common use of this method is in determining the flood discharge of a stream when the only data available are the cross section, the slope as shown by marks along the bank, and a knowledge of the general conditions.

Weir methods.—When funds are available and the conditions are such that sharp-crested weirs can be erected, these offer the best facilities for determining flow. If dams are suitably situated and constructed they may be utilized for obtaining reliable measurements of flow. The conditions necessary to insure good results may be divided into two classes—(1) those relating to the physical characteristics of the dam itself, and (2) those relating to the diversion and use of water around and through the dam.

The physical requirements are as follows: (*a*) Sufficient height of dam, so that backwater will not interfere with free fall over it; (*b*) absence of leaks of appreciable magnitude; (*c*) topography or abutments which confine the flow over the dam at high stages; (*d*) level crests, which are kept free from obstructions caused by floating logs or ice; (*e*) crests of a type for which the coefficients to be used in $Q=c\,b\,h^{\frac{3}{2}}$, or some similar standard weir formula, are known (see Water-Supply Papers Nos. 180 and 200[a]); (*f*) either no flashboards or exceptional care in reducing leakage through them and in recording their condition.

Preferably there should be no diversion of water through or around the dam. Generally, however, the dam is built for purposes of power or navigation, and part or all of the water flowing past it is diverted for such uses. This water is measured and added to that passing over the dam. To insure accuracy in such determinations of flow the amount of water diverted should be reasonably constant. Furthermore, it should be so diverted that it can be measured, either by a weir, a current meter, or a simple system of water wheels which are of standard make, or which have been rated as meters under working conditions and so installed that the gate openings, the heads under which they work, and their angular velocities may be accurately observed.

---

[a] Water-Supply Paper No. 200 replaces No. 150, the edition of which has been exhausted.

The combination of physical conditions and uses of water should be such that the determinations of flow will not involve, for a critical stage of considerable duration, the use of a head on a broad-crested dam, of less than 6 inches. Moreover, when all other conditions are good, the cooperation of the owners or operators of the plant is still essential if reliable results are to be obtained.

A gaging station at a weir or dam has the general advantage of continuity of record through the periods of ice and floods, and the disadvantages of uncertainty of coefficient to be used in the weir formula and of complications in the diversion and use of the water.

Velocity method.—The determination of the quantity of water flowing past a certain section of a stream at a given time is termed a discharge measurement. This quantity is the product of two factors—the mean velocity and the area of the cross section. The mean velocity is a function of surface slope, wetted perimeter, roughness of bed, and the channel conditions at, above, and below the gaging section. The area depends on the contour of the bed and the fluctuations of the water surface. The two principal ways of measuring the velocity of a stream are by floats and current meters.

Great care is taken in the selection and equipment of gaging stations for determining discharge by velocity measurements in order that the data may have the required degree of accuracy. Their essential requirements are practically the same whether the velocity is determined by meters or floats. They are located as far as possible where the channel is straight both above and below the gaging section; where there are no cross currents, backwater, or boils; where the bed of the stream is reasonably free from large projections of a permanent character; and where the banks are high and subject to overflow only at flood stages. The station must be so far removed from the effects of tributary streams and of dams or other artificial obstructions that the gage height shall be an index of the discharge.

Certain permanent or semipermanent structures, usually referred to as "equipment," are generally pertinent to a gaging station. These are a gage for determining the fluctuations of the water surface, bench marks to which the datum of the gage is referred, permanent marks on a bridge or a tagged line indicating the points of measurement, and, where the current is swift, some appliance (generally a secondary cable) to hold the meter in position in the water. As a rule, the stations are located at bridges if the channel conditions are satisfactory, as from them the observations can more readily be made and the cost of the equipment is small.

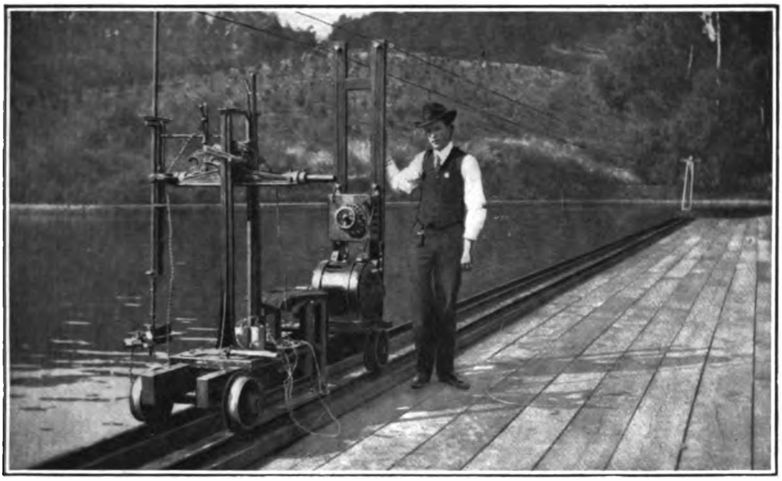
The floats in common use are the surface, subsurface, and tube or rod floats. A corked bottle with a flag in the top and weighted at the bottom makes one of the most satisfactory surface floats, as it is affected but little by wind. In case of flood measurements, good results can be obtained by observing the velocity of floating cakes of ice or débris. In case of all surface-float measurements coefficients must be used to reduce the observed velocity to the mean velocity. The subsurface and tube or rod floats are intended to give directly the mean velocity in the vertical. Tubes give excellent results when the channel conditions are good, as in canals.

In measuring velocity by a float, observation is made of the time taken by the float to pass over the "run," a selected stretch of river from 50 to 200 feet long. In each discharge measurement a large number of velocity determinations are made at different points across the stream, and from these observations the mean velocity for the whole section is determined. This may be done by plotting the mean positions of the floats as indicated by the distances from the bank as ordinates and the corresponding times as abscissas. A curve through these points shows the mean time of run at any point across the stream, and the mean time for the whole stream is obtained by dividing the area bounded by this curve and its axis by the width. The length of the run divided by the mean time gives the mean velocity.

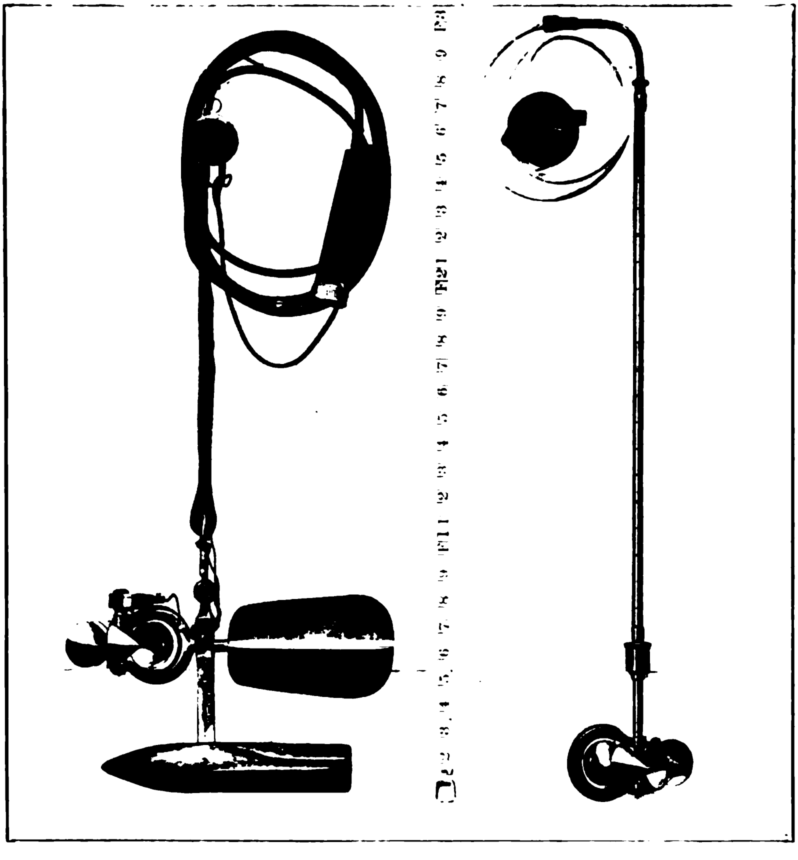
The area used in float measurements is the mean of the areas at the two ends of the run and at several intermediate sections.

The essential parts of the current meters in use are a wheel of some type so constructed that the impact of flowing water causes it to revolve and a device for recording or indicating the number of revolutions. The relation between the velocity of the moving water and the revolutions of the wheel is determined for each meter. This rating is done by drawing the meter through still water for a given distance at different speeds and noting the number of revolutions for each run. From these data a rating table is prepared which gives the velocity per second for any number of revolutions.

Many kinds of current meters have been constructed. They may, however, be classed in two general types—those in which the wheel is made up of a series of cups, as the Price, and those having a screw-propeller wheel, as the Haskell. Each meter has been developed for use under some special condition. In the case of the small Price meter, shown in Pl. II, *B*, which has been largely developed and extensively used by the United States Geological Survey, an attempt has been made to get an instrument which could be used under practically all conditions.



A. CURRENT-METER RATING STATION, LOS ANGELES, CAL.



B. PRICE CURRENT METERS.

Current-meter measurements may be made from a bridge, cable, boat, or by wading, and gaging stations may be classified in accordance with such use. Fig. 1 shows a typical cable station.

In making the measurement an arbitrary number of points are laid off on a line perpendicular to the thread of the stream. The points at which the velocity and depth are observed are known as measuring points and are usually fixed at regular intervals, varying from 2 to 20 feet, depending on the size and condition of the stream. Perpendiculars dropped from the measuring points divide the gaging section into strips. For each strip or pair of strips the mean velocity, area, and discharge are determined independently, so that conditions existing in one part of the stream may not be extended to parts where they do not apply.

Three classes of methods of measuring velocity with current meters are in general use—multiple-point, single-point, and integration.

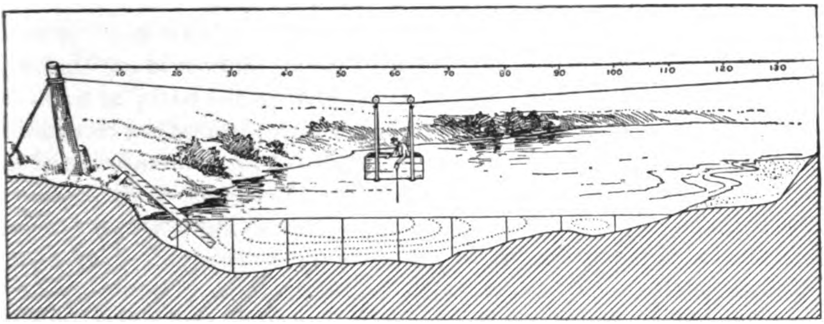


FIG. 1.—Cable station showing section of the river, car, gage, etc.

The three principal multiple-point methods in general use are the vertical velocity-curve; 0.2 and 0.8 depth; and top, bottom, and mid-depth.

In the vertical velocity-curve method a series of velocity determinations are made in each vertical at regular intervals, usually from 0.5 to 1 foot apart. By plotting these velocities as abscissas and their depths as ordinates and drawing a smooth curve among the resulting points the vertical velocity-curve is developed. This curve shows, graphically, the magnitude and changes in velocity from the surface to the bottom of the stream. The mean velocity in the vertical is then obtained by dividing the area bounded by this velocity curve and its axis by the depth. On account of the length of time required to make a complete measurement by this method its use is limited to the determination of coefficients for purposes of comparison and to measurements under ice.

In the second multiple-point method the meter is held successively at 0.2 and 0.8 of the depth, and the mean of the velocities at these two points is taken as the mean velocity for that vertical. On the assumption that the vertical velocity-curve is a common parabola with horizontal axis, the mean of the velocities at 0.22 and 0.79 of the depth will give (closely) the mean velocity in the vertical. Actual observations under a wide range of conditions show that this second multiple-point method gives the mean velocity very closely for open-water conditions, and, moreover, the indications are that it holds nearly as well for ice-covered rivers.

In the third multiple-point method the meter is held at mid-depth, at 0.5 foot below the surface, and at 0.5 foot above the bottom, and the mean velocity is determined by dividing by 6 the sum of the top velocity, four times the mid-depth velocity, and the bottom velocity. The method may be modified by observing at 0.2, 0.6, and 0.8 depth.

The single-point method consists in holding the meter either at the depth of the thread of mean velocity or at an arbitrary depth for which the coefficient for reducing to mean velocity has been determined.

Extensive experiments by vertical velocity-curves show that the thread of mean velocity generally occurs at from 0.3 to 0.7 of the total depth. In general practice the thread of mean velocity is considered to be at 0.6 depth, at which point the meter is held in a majority of the measurements. A large number of vertical velocity-curve measurements, taken on many streams and under varying conditions, show that the average coefficient for reducing the velocity obtained at 0.6 depth to mean velocity is practically unity.

In the other principal single-point method the meter is held near the surface, usually 1 foot below or low enough to be out of the effect of the wind or other disturbing influences. This is known as the subsurface method. The coefficient for reducing the velocity taken at the subsurface to the mean has been found to be from 0.85 to 0.95, depending on the stage, velocity, and channel conditions. The higher the stage the larger the coefficient. This method is specially adapted for flood measurements or when the velocity is so great that the meter can not be kept at 0.6 depth.

The vertical-integration method consists in moving the meter at a slow uniform speed from the surface to the bottom and back again to the surface and noting the number of revolutions and the time taken in the operation. This method has the advantage that the velocity at each point of the vertical is measured twice. It is useful as a check on the point methods.

The area, which is the other factor in the velocity method of determining the discharge of a stream, depends on the stage of the river, which is observed on the gage, and on the general contour of the bed of the stream, which is determined by soundings. The soundings are usually taken at each measuring point at the time of the discharge measurement either by using the meter and cable or by a special sounding line or rod. For streams with permanent beds standard cross sections are usually taken during low water. These sections serve to check the soundings which are taken at the time of the measurements, and from them any change which may have taken place in the bed of the stream can be detected. They are also of value in obtaining the area for use in computations of high-water measurements, as accurate soundings are hard to obtain at high stages.

In computing the discharge measurements from the observed velocities and depths at various points of measurement the measuring section is divided into elementary strips, as shown in fig. 1, and the mean velocity, area, and discharge are determined separately for either a single or a double strip. The total discharge and the area are the sums of those for the various strips, and the mean velocity is obtained by dividing the total discharge by the total area.

The determination of the flow of an ice-covered stream is difficult, owing to diversity and instability of conditions during the winter period, and also to lack of definite information in regard to the laws of flow of water under ice. The method now employed is to make frequent discharge measurements during the frozen periods by the 0.2 and 0.8, and vertical velocity-curve methods, and to keep an accurate record of the conditions, such as the gage height to the surface of the water as it rises in a hole cut in the ice, the thickness and character of the ice, etc. From these data an approximate estimate of the daily flow can be made by constructing a rating curve (really a series of curves) similar to that used for open channels, but considering, in addition to gage heights and discharge, the varying thickness of ice.

For information in regard to flow under ice cover see Water-Supply Paper No. 187.

OFFICE METHODS OF COMPUTING RUN-OFF.

There are two principal methods of determining run-off, depending upon whether or not the bed of the stream is permanent.

For stations of streams with permanent beds the first step in computing the run-off is the construction of a rating table, which shows the discharge corresponding to any stage of the stream. This rating table is applied to the record of stage to determine the amount of water flowing. The construction of the rating table depends on the method used in measuring flow.

For a station at a weir or dam the basis for the rating table is some standard weir formula. The coefficients to be used in its application depend on the type of dam and other conditions near its crest. After inserting in the weir formula the measured length of crest and the assumed coefficient, the discharge is computed for various heads and the rating table constructed.

The data necessary for the construction of a rating table for a velocity-area station are the results of the discharge measurements, which include the record of stage of the river at the time of measurement, the area of the cross section, the mean velocity of the current, and the quantity of water flowing. A thorough knowledge of the conditions at and in the vicinity of the station is also necessary.

The construction of the rating table depends on the following laws of flow for open permanent channels: (1) The discharge will remain constant so long as conditions at or near the gaging station remain constant. (2) The discharge will be the same whenever the stream is at a given stage if the change of slope due to the rise and fall of the stream be neglected. (3) The discharge is a function of and increases gradually with the stage.

The plotting of results of the various discharge measurements, using gage heights as ordinates; and discharge, mean velocity, and area as abscissas will define curves which show the discharge, mean velocity, and area corresponding to any gage height. For the development of these curves there should be, therefore, a sufficient number of discharge measurements to cover the range of the stage of the stream. Fig. 2 shows a typical rating curve with its corresponding mean-velocity and area curves.

As the discharge is the product of two factors, the area and the mean velocity, any change in either factor will produce a corresponding change in the discharge. Their curves are therefore constructed in order to study each independently of the other.

The area curve can be definitely determined from accurate soundings extending to the limits of high water. It is always concave toward the horizontal axis or on a straight line, unless the banks of the stream are overhanging.

The form of the mean-velocity curve depends chiefly on the surface slope, the roughness of the bed, and the cross section of the stream. Of these, the slope is the principal factor. In accordance with the relative changes of these factors the curve may be either a straight line, convex or concave toward either axis, or a combination of the three. From a careful study of the conditions at any gaging station the form which the vertical velocity-curve will take can be predicted, and it may be extended with reasonable certainty to stages beyond the limits of actual measurements. Its principal use is in connection with the area curve in locating errors in discharge measurements and in constructing the rating table.

The discharge curve is defined primarily by the measurements of discharge, which are studied and weighted in accordance with the local conditions existing at the time of each measurement. The curve may,

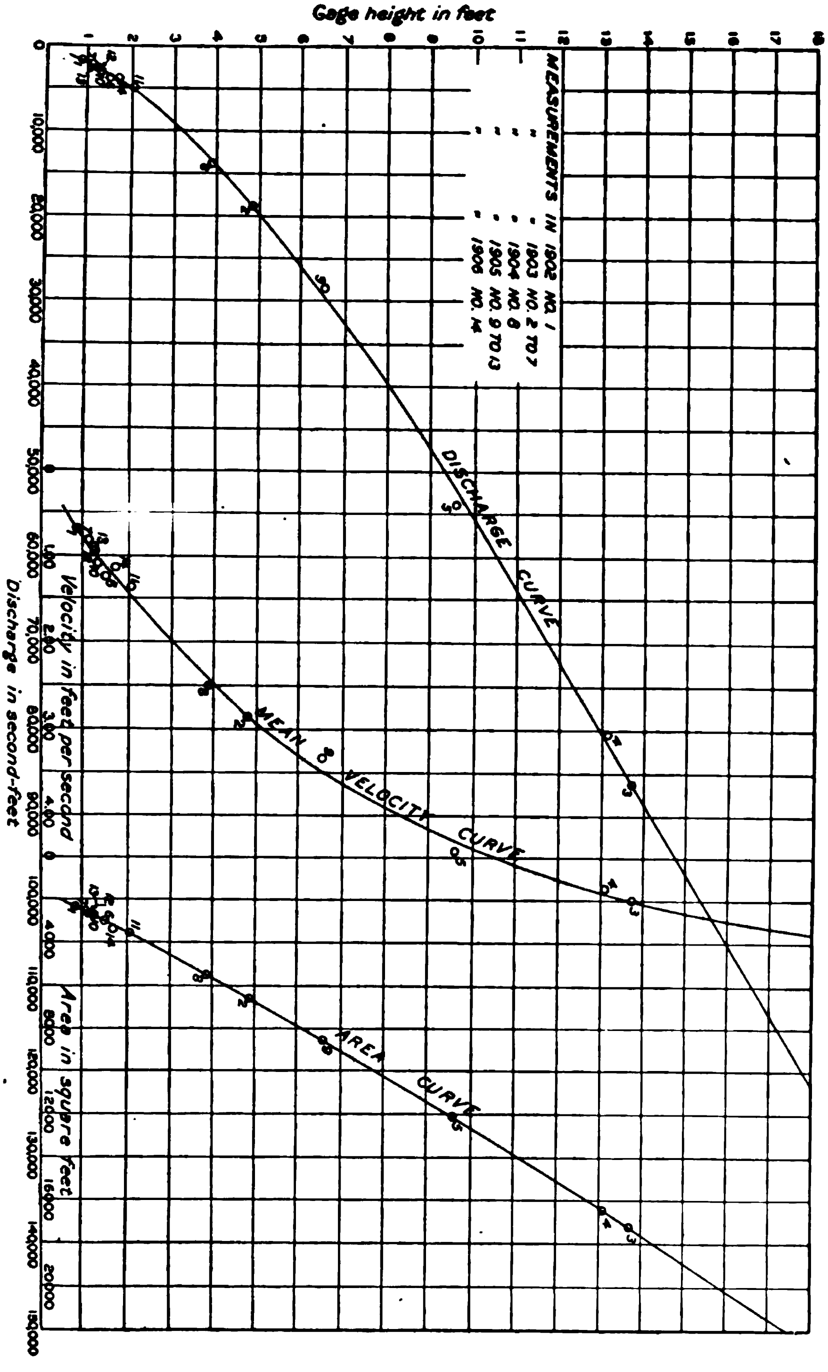


Fig. 2.—Typical discharge, area, and mean-velocity curves.

however, best be located between and beyond the measurements by means of curves of area and mean velocity. The discharge curve under normal conditions is concave toward the horizontal axis and is generally parabolic in form.

In the preparation of the rating table the discharge for each tenth or half tenth on the gage is taken from the curve. The differences between successive discharges are then taken and adjusted according to the law that they shall be either constant or increasing.

The determination of daily discharge of streams with changeable beds is a difficult problem. In case there is a weir or dam available, a condition which seldom exists on streams of this class, the discharge can be determined by its use. In case of velocity-area stations frequent discharge measurements must be made if the determinations of flow are to be other than rough approximations. For stations with beds which shift slowly, or are materially changed only during floods, rating tables can be prepared for periods between such changes and satisfactory results obtained with a limited number of measurements, provided that some of them are taken soon after the change occurs. For streams with continually shifting beds, such as the Colorado and Rio Grande, discharge measurements should be made every two or three days and the discharges for intervening days obtained either by interpolation modified by gage height or by Professor Stout's method, which has been described in full in the Nineteenth Annual Report of the United States Geological Survey, Part IV, page 323, and in the Engineering News of April 21, 1904. This method, or a graphical application of it, is also much used in determining the flow at stations where the bed shifts but slowly.

COOPERATION AND ACKNOWLEDGMENTS.

Special acknowledgments are due to John H. Lewis, State engineer of Oregon, for cooperation in accordance with the provisions of section 10, chapter 228, Laws of Oregon for 1905, "Hydrographic and topographic surveys in cooperation with the United States Government," which provides $2,500 annually for hydrographic surveys, "such appropriations, however, being contingent upon the United States Government making a like apportionment for such purposes to be expended within the State."

In 1906 the cooperative fund of $2,500 appropriated by the State of Oregon was largely spent under the direction of the State engineer in western Oregon, the Geological Survey retaining supervision of the work and publishing the results without expense to the State; but the Federal Survey, realizing the benefits to be derived by a more extensive study of the water resources of the State than could be accomplished by merely meeting the State's appropriation, expended on hydrographic work in Oregon the sum of $5,533 during the calendar year 1906.

Assistance has been rendered or records furnished by the following, to whom acknowledgments are due:

The officers and employees of the United States Weather Bureau; Corps of Engineers, U. S. Army; Meteorological Service of Department of Marine and Fisheries, Canada; for climatological and hydrographic data.

Oregon Railroad and Navigation Company; Southern Pacific Company; Oregon Short Line Railroad; Northern Pacific Railroad; Sumpter Valley Railway; and Columbia Southern Railway; for transportation.

J. G. Kelley, Portland, Oreg.; Charles Gilman Hyde, University of California, Berkeley; R. H. McKee, Seattle, Wash.; Frank C. Kelsey and Williard Young, Portland, Oreg.; for results of measurements and other hydrographic data, collected by them and furnished gratis.

Deschutes Irrigation and Power Company, Portland, Oreg.; Columbia Southern Irrigating Company, Portland, Oreg.; Squaw Creek Irrigation Company, Prineville, Oreg.; Lewiston-Clarkston Company, Clarkston, Wash.; Seattle-Tacoma Power Company, Seattle, Wash.; Northwestern Gas and Electric Company, Pendleton, Oreg.; Condor Water and Power Company, Tolo, Oreg.; M. W. Zindel, Zindel, Wash.; and the citizens of Union, Oreg., and Sisters, Oreg.; for voluntary observations of gage heights.

COLUMBIA RIVER DRAINAGE.

COLUMBIA RIVER PROPER.

DESCRIPTION OF BASIN.

Columbia River has its source in Columbia Lake in the east division of the Kootenai district in British Columbia; thence it flows northward to the fifty-second parallel of latitude, where it turns sharply southward and flows through a series of arrowlike lakes, crossing the international boundary line in the northeast corner of the State of Washington, where it receives the Clark Fork. After traversing the State of Washington it forms the boundary line between Washington and Oregon and empties into the Pacific Ocean at the forty-sixth parallel of latitude. The river is navigable in long stretches throughout its entire course in the United States, although, owing to rapids and falls, continuous navigation is not possible.

The Columbia and its tributaries drain a total area of 259,000 square miles, distributed as follows:

Areas in Columbia River basin.

	Square miles.
Oregon	55,370
Washington	48,000
Idaho	81,380
Montana	25,000
Nevada	5,280
Wyoming	5,270
British Columbia	38,700

The larger part of this area is arid or semiarid, the annual rainfall varying from 10 inches in portions of Oregon and Idaho to 100 inches on the Cascade Range. The area is largely mountainous, and the streams flow for the most part through deep canyons in the basaltic formations characteristic of the Pacific Northwest. The flood discharge of the Columbia at The Dalles has been estimated at 1,000,000 second-feet and the low-water flow at about 40,000 second-feet.

The tributaries of the Columbia are of great importance, affording good sites for the development of power and an abundance of water for irrigation, which latter is extensively practiced in some of the valleys, notably those of Umatilla, Yakima, and the upper portion of Snake River.

The basins of Naches, Boise, and Walla Walla rivers and other tributary streams are described in connection with gaging stations maintained on them.

On the Columbia proper but one gaging station—that at Pasco—is maintained by the Geological Survey. Others, however, are maintained by the United States Weather Bureau at Riparia, Wenatchee, Umatilla, The Dalles, and Vancouver, and by the United States Corps of Engineers at Celilo, Cascade Locks, and Fort Stevens.

COLUMBIA RIVER AT PASCO, WASH.

This station was established October 15, 1904, at the bridge of the Northern Pacific Railway, 1.2 miles from Pasco, Wash. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 13, where are given also references to publications that contain data for previous years.

Daily gage height, in feet, of Columbia River at Pasco, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.7	8.0	9.3	11.4	17.8	21.0	19.7	17.5	12.9	11.6	11.0	11.8
2	7.7	8.1	9.2	12.2	18.1	20.9	19.7	17.4	12.8	11.5	10.8	11.7
3	7.6	8.2	9.2	13.0	18.5	20.8	19.7	17.4	12.8	11.4	10.8	11.6
4	7.6	8.2	9.2	13.0	18.8	20.8	19.7	17.2	12.8	11.3	10.8	11.4
5	7.6	8.3	9.1	12.8	19.2	21.0	19.7	17.0	12.7	11.2	10.7	11.3
6	7.6	8.3	9.0	12.6	19.3	21.0	19.7	16.8	12.7	11.1	10.6	11.2
7	7.5	8.2	9.0	12.6	19.2	21.1	19.7	16.5	12.7	11.0	10.6	11.1
8	7.5	8.1	8.9	13.0	19.1	21.1	19.8	16.1	12.6	10.9	10.6	11.1
9	7.5	8.1	9.0	13.4	19.0	21.0	19.9	15.9	12.6	10.9	10.7	11.1
10	7.5	8.0	9.1	13.9	19.0	20.9	20.1	15.6	12.5	10.8	10.9	11.1
11	7.4	7.9	9.1	14.4	19.3	20.8	20.3	15.4	12.5	10.7	10.7	11.0
12	7.4	7.9	9.2	14.4	19.7	20.8	20.4	15.3	12.8	10.6	10.8	11.0
13	7.4	7.9	9.2	14.3	20.1	20.9	20.5	15.1	13.2	10.6	10.9	11.0
14	7.5	7.9	9.0	14.1	20.3	21.1	20.6	15.0	13.5	10.5	11.4	11.0
15	7.5	7.9	8.9	13.8	20.3	21.1	20.6	15.0	13.7	10.5	14.0	10.9
16	7.5	7.8	8.8	13.8	20.2	21.0	20.6	15.0	13.7	10.5	16.6	10.8
17	7.4	7.8	8.7	14.0	20.2	21.0	20.5	15.0	13.5	10.5	17.5	10.6
18	7.4	7.8	8.4	14.3	20.1	21.1	20.4	15.0	13.3	10.5	16.3	10.6
19	7.4	7.8	8.3	14.6	20.0	20.9	20.2	15.0	13.1	10.6	15.3	10.5
20	7.4	8.0	8.3	14.9	20.0	20.7	20.0	15.0	12.8	10.6	14.0	10.4
21	7.4	8.8	8.3	15.1	19.9	20.5	19.9	14.9	12.6	10.6	13.3	10.6
22	7.4	9.0	8.3	15.3	19.9	20.1	19.7	14.7	12.4	10.6	13.1	11.4
23	7.3	9.2	8.3	15.9	19.9	20.0	19.4	14.6	12.2	10.6	12.9	11.4
24	7.4	9.3	8.3	16.6	19.9	19.8	19.2	14.4	12.0	10.5	12.8	11.3
25	7.4	9.3	8.4	17.2	19.9	19.5	19.0	14.3	12.0	10.5	12.6	11.3
26	7.6	9.3	8.7	17.6	20.0	19.5	18.8	14.0	12.0	10.4	12.4	11.4
27	7.8	9.3	9.4	17.6	20.2	19.3	18.6	13.8	11.9	10.3	12.2	11.7
28	8.0	9.3	10.2	17.5	20.8	19.3	18.4	13.6	11.8	11.2	12.0	11.7
29	8.0	....	10.9	17.4	20.8	19.3	18.2	13.4	11.7	11.7	11.9	11.8
30	8.0	....	11.3	17.5	20.8	19.5	18.0	13.2	11.7	11.4	11.9	11.6
31	8.0	....	11.2	....	21.0	....	17.9	13.0	....	11.1	....	11.6

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made on minor streams directly tributary to Columbia River during 1906:

Miscellaneous measurements in Columbia River drainage basin in 1906.

Date.	Stream.	Locality.	Width.	Area of section.	Gage height.	Discharge.
			Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
September 10	Eightmile Creek	The Dalles, Oreg	....	....	....	[a] 7
April 26	Sandy River	3½ miles southeast of Troutdale, Oreg.	202	1,320	....	3,050
July 27	do	do	180	774	[b] 1.18	703
August 31 [c]	do	Salmon River post-office, Oreg.	88	154	1.15	397
September 1	do	Troutdale, Oreg	178	750	[b] 1.55	475
September 30	do	do	183	844	[d] 4.87	688
September 27	Still River	SW. ¼ sec. 13, T. 3 S., R. 7 E.	20	22	....	53
August 31	Salmon River	Salmon River post-office, Oreg.	71	117	....	120
September 27	Zigzag Creek	NE. ¼ sec. 17, T. 3 S., R. 7 E.	22	14	[e] 2.80	44
September 1	Bull Run Creek	Above Portland waterworks pipe intake.	74	183	....	93
September 1	do	do	74	177	....	110
June 30	Bull Run Creek pipe	Headworks	14.5	52	....	38
September 1	do	do	14.5	46	....	38

[a] Estimated.

[b] Below top portion of lower section of bridge caisson, right bank.

[c] Below junction of Salmon River.

[d] Below top of bridge caisson, left bank, downstream side.

[e] Below nail in alder on south bank 20 feet upstream from footbridge.

CLARK FORK DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Clark Fork[a] rises on the eastern slopes of the high mountain ranges that form the boundary between Montana and Idaho. It flows northward, northwestward, and again northward as it crosses western Montana, northern Idaho (through Lake Pend Oreille), northeastern Washington, and a few miles into British Columbia, then turns somewhat abruptly westward and southwestward and joins the Columbia near Boundary station on the Spokane Falls and Northern Railroad.

To the river thus described various names have been applied in the past and are probably still used locally. The northward-flowing section above the town of Missoula has been known as the Bitterroot, the section between the junction of Hell Gate and Big Blackfoot rivers and Lake Pend Oreille has been called the Missoula, and the stretch of the river below its exit from Lake Pend Oreille has been called Pend Oreille River. These names, as well as Silver Bow, Hell Gate, and Deer Lodge, have been superseded, a recent decision of the Board on Geographic Names applying Clark Fork to the stream continuously from the head of the Bitterroot to the mouth of the Pend Oreille.

CLARK FORK[b] NEAR GRANTSDALE, MONT.

This station was established April 25, 1902. It is located on the highway bridge 2 miles southwest of Grantsdale and 5 miles southwest of Hamilton, Mont. Length of chain in 1906, 23.25 feet. The bench mark is the northwest bolt in the northwest abutment of the bridge; elevation above gage datum, 19.36 feet. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 21, where are given also references to publications that contain data for previous years.

Discharge measurements of Clark Fork near Grantsville, Mont., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 7	Morse and Edson	172	403	2.26	798
April 27	G. Edson	186	567	3.27	1,970
June 5	do	193	744	4.10	3,830
July 7	Morse and Richards	183	486	2.95	1,460
August 11 [c]	R. Richards	29	57	1.24	99
September 9 [c]	do	37	56	1.24	114

---

[a] Clark Fork; river in Idaho, Montana, and Washington. (Not Bitter Root, Bitterroot, Clarke, Clarks River, Deer Lodge, Deerlodge, Hell Gate, Hellgate, Missoula, Silver Bow, nor Silverbow:) Third Report U. S. Board on Geographic Names, Washington, 1907, p. 51.

[b] Station formerly known as Bitterroot River near Grantsdale, Mont.

[c] Measured by wading.

Daily gage height, in feet, of Clark Fork near Grantsdale, Mont., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.8	1.5	1.6	2.35	3.3	3.6	3.0	1.4	1.3	1.4	2.1	2.15
2	1.8	1.5	1.6	2.25	3.2	3.5	3.0	1.5	1.3	1.4	2.0	2.15
3	1.8	1.5	1.6	2.15	3.4	3.5	3.1	1.4	1.3	1.4	2.0	2.1
4	1.8	1.7	1.6	1.95	3.8	4.0	3.1	1.3	1.2	1.4	2.0	2.1
5	1.8	1.7	1.6	1.95	3.6	4.0	3.0	1.3	1.2	1.5	1.9	2.1
6	1.8	1.6	1.6	2.25	3.5	4.1	3.0	1.6	1.2	1.5	1.9	2.5
7	1.8	1.6	1.6	2.35	3.5	3.9	3.0	1.5	1.2	1.5	1.9	2.4
8	1.8	1.5	1.6	2.35	3.7	3.7	2.9	1.4	1.2	1.5	2.95	2.35
9	1.9	1.8	1.7	2.45	3.8	3.5	2.8	1.3	1.2	1.5	2.7	2.35
10	1.9	1.8	1.7	2.45	4.0	4.0	2.8	1.3	1.2	1.5	2.5	2.3
11	1.9	1.8	2.5	2.35	4.2	4.3	2.6	1.2	1.2	1.5	2.4	2.3
12	2.3	1.8	2.5	2.35	4.2	4.4	2.6	1.3	1.3	1.5	3.0	2.25
13	2.3	1.7	2.5	2.25	4.3	4.1	2.5	1.2	1.4	1.5	4.1	2.2
14	2.3	1.7	2.5	2.25	4.1	4.0	2.4	1.2	1.5	1.5	4.6	2.1
15	2.3	1.6	2.5	2.55	4.0	3.9	2.3	1.2	1.5	1.5	6.02	2.05
16	2.3	1.6	2.5	2.55	3.8	3.7	2.2	1.2	1.5	1.6	5.0	2.15
17	1.8	1.6	2.5	2.65	3.7	3.6	2.1	1.2	1.5	1.75	4.05	2.15
18	1.7	1.5	2.3	2.65	3.6	3.5	2.2	1.2	1.5	1.7	3.55	2.1
19	1.8	1.5	2.2	2.65	3.4	3.4	2.1	1.2	1.5	1.7	3.25	2.1
20	1.8	1.6	2.0	2.75	3.3	3.3	2.0	1.1	1.6	1.7	3.0	2.1
21	1.8	1.6	1.8	3.05	3.5	3.2	1.9	1.1	1.6	1.65	2.7	2.2
22	1.7	1.6	1.8	3.45	3.4	3.1	1.9	1.3	1.6	1.6	2.6	2.25
23	1.7	1.6	1.8	3.85	3.4	3.0	1.9	1.4	1.6	1.65	2.5	2.25
24	1.7	1.6	1.7	4.15	3.5	3.0	1.8	1.4	1.5	1.65	2.35	2.2
25	1.6	1.6	2.1	3.85	4.0	3.1	1.7	1.5	1.5	1.7	2.3	2.2
26	1.6	1.6	2.0	3.45	4.3	3.2	1.7	1.5	1.5	1.9	2.3	2.25
27	1.6	1.6	2.0	3.25	4.4	3.3	1.5	1.5	1.5	2.9	2.25	2.3
28	1.6	1.6	2.0	3.2	4.3	3.8	1.5	1.4	1.4	2.7	2.25	2.3
29	1.6	......	2.0	3.3	4.0	3.5	1.3	1.4	1.4	2.5	2.2	2.25
30	1.5	......	2.0	3.3	3.9	3.4	1.4	1.3	1.4	2.4	2.15	2.35
31	1.5	......	2.2	......	3.8	......	1.3	1.3	......	2.2	......	2.4

NOTE.—Ice conditions January 12 to 17 and February 9 to March 21.

Rating table for Clark Fork near Grantsdale, Mont., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.10	60	1.80	395	2.50	1,020	3.20	1.825	3.90	3,005
1.20	80	1.90	470	2.60	1,120	3.30	1,965	4.00	3,215
1.30	110	2.00	550	2.70	1,225	3.40	2,105	4.20	3,660
1.40	150	2.10	635	2.80	1,335	3.50	2,265	4.40	4,110
1.50	200	2.20	725	2.90	1,450	3.60	2,435		
1.60	260	2.30	820	3.00	1,570	3.70	2,615		
1.70	325	2.40	920	3.10	1,695	3.80	2,805		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 17 discharge measurements made during 1904–1906 and is well defined.

Monthly discharge of Clark Fork near Grantsdale, Mont., for 1906.

[Drainage area, 1,550 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January [a]	470	200	359	22,100	0.232	0.27
February 1–8	325	200	246	3,900	.159	.05
March 22–31	725	325	522	10,400	.337	.13
April	3,550	510	1,370	81,500	.884	.99
May	4,110	1,825	2,800	172,000	1.81	2.09
June	4,110	1,570	2,540	151,000	1.64	1.83
July	1,700	110	866	53,200	.559	.64
August	260	60	127	7,810	.082	.09
September	260	80	157	9,340	.101	.11
October	1,450	150	386	23,700	.249	.29
November	8,100	470	1,650	98,200	1.06	1.18
December	1,020	592	750	46,100	.484	.56
The period	....	....	....	679,000	....	....

[a] Discharge estimated January 12 to 17.

NOTE.—Values are rated as follows: January to March and August to October, good; remainder of the period, excellent.

CLARK FORK [a] AT MISSOULA, MONT.

This station was established July 10, 1898, at Higgins Avenue Bridge, Missoula, Mont., but was removed May 27, 1899, to the bridge of the Bitterroot Valley division of the Northern Pacific Railway, about one-half mile downstream. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 16, where are given also references to publications that contain data for previous years.

Discharge measurements of Clark Fork at Missoula, Mont., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 6	Morse and Edson	195	833	3.43	1,750
April 6	do	195	813	3.45	1,650
April 26	G. Edson	275	1,250	4.90	4,230
June 6	do	306	1,480	6.08	7,370
July 6	Morse and Richards	172	912	4.13	2,690
August 10	R. Richards	162	715	3.08	1,070
September 8	do	137	699	2.77	1,050
September 19	Grover and Follansbee	162	733	3.07	1,050
October 15	Richards and Follansbee	162	723	2.93	972

Daily gage height, in feet, of Clark Fork at Missoula, Mont., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.10	3.30	2.80	4.12	4.52	5.70	4.70	3.08	3.05	2.85	3.25	3.60
2	3.10	3.30	2.68	4.18	4.50	5.60	4.62	3.02	3.00	2.90	3.20	3.60
3	3.10	3.35	2.60	3.78	4.58	5.65	4.62	3.00	3.00	2.90	3.20	3.60
4	3.10	3.35	2.65	3.50	4.80	5.72	4.48	3.00	3.00	2.85	3.25	3.62
5	3.10	3.35	2.70	3.42	4.85	5.95	4.32	3.00	2.98	2.90	3.20	3.78
6	3.10	3.35	2.80	3.45	4.80	6.02	4.25	3.00	2.90	2.90	3.20	3.70
7	3.10	3.35	2.90	3.60	4.65	6.12	4.10	3.00	2.85	2.90	3.22	3.72
8	3.10	3.35	2.95	3.70	4.62	5.95	4.00	3.10	2.78	2.90	3.45	3.75
9	3.12	3.35	2.95	3.75	4.75	5.80	3.98	3.15	2.78	2.85	3.60	3.70
10	3.15	3.35	2.95	3.72	4.80	5.72	3.95	3.15	2.75	2.85	3.60	3.65
11	3.15	3.35	2.95	3.68	5.00	5.72	3.88	2.95	2.85	2.90	3.65	3.68
12	3.20	3.35	2.95	3.62	5.25	5.72	3.80	2.95	2.85	2.90	3.60	3.75
13	3.20	3.35	2.95	3.58	5.38	5.78	3.72	3.00	2.85	2.95	3.68	3.80
14	3.20	3.35	2.95	3.52	5.40	5.78	3.60	3.05	2.90	2.95	4.20	3.68
15	3.20	3.35	2.95	3.52	5.30	5.62	3.65	3.00	3.18	2.95	5.00	3.48
16	3.20	3.35	2.95	3.60	5.30	5.48	3.70	3.00	3.32	2.95	5.18	3.45
17	3.20	3.35	3.15	3.72	5.15	5.60	3.62	2.92	3.22	3.05	5.15	3.48
18	3.20	3.35	3.25	3.80	5.00	5.50	3.58	2.82	3.08	3.08	4.70	3.58
19	3.25	3.35	3.25	3.88	4.85	5.28	3.50	2.82	3.10	3.10	4.48	3.70
20	3.25	3.35	3.40	3.90	4.80	5.10	3.45	2.80	3.05	3.15	4.28	3.68
21	3.10	3.35	3.40	4.00	4.80	5.02	3.40	2.78	3.08	3.10	4.35	3.65
22	3.30	2.90	3.30	4.25	4.88	4.98	3.40	2.75	3.05	3.05	4.22	3.60
23	3.30	2.80	3.30	4.55	4.90	4.90	3.35	3.10	3.00	3.05	4.15	3.60
24	3.30	2.70	3.98	4.90	4.90	4.80	3.30	3.25	2.98	3.05	4.02	3.60
25	3.30	2.60	3.95	5.00	4.98	4.78	3.22	3.28	2.92	3.05	4.00	3.65
26	3.30	2.80	4.35	4.88	4.98	4.70	3.20	3.35	2.95	3.22	3.98	3.75
27	3.30	2.80	4.25	4.80	5.10	4.60	3.12	3.30	2.95	3.30	3.70	3.80
28	3.30	2.80	3.95	4.75	5.30	4.70	3.10	3.22	2.95	3.25	3.60	3.80
29	3.30	....	3.90	4.70	5.55	4.80	3.10	3.15	2.90	3.25	3.70	3.75
30	3.30	....	3.85	4.62	5.78	4.78	3.10	3.10	2.90	3.25	3.60	3.70
31	3.30	....	3.92	....	5.75	....	3.10	3.08	....	3.25	....	3.60

NOTE.—Ice conditions January 2 to February 19 and March 10 to 24. There was no ice during December.

[a] Station formerly known as Missoula River at Missoula, Mont.

Rating table for Clark Fork at Missoula. Mont., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.50	750	3.30	1,440	4.10	2,610	4.90	4,230	5.60	5,990
2.60	810	3.40	1,560	4.20	2,790	5.00	4,460	5.70	6,270
2.70	880	3.50	1,690	4.30	2,970	5.10	4,700	5.80	6,550
2.80	950	3.60	1,830	4.40	3,160	5.20	4,950	5.90	6,840
2.90	1,030	3.70	1,970	4.50	3,360	5.30	5,200	6.00	7,130
3.00	1,120	3.80	2,120	4.60	3,570	5.40	5,460	6.20	7,740
3.10	1,220	3.90	2,280	4.70	3,780	5.50	5,720	6.40	8,370
3.20	1,330	4.00	2,440	4.80	4,000				

NOTE.—The above table is applicable only for open-channel conditions. It is based on 9 discharge measurements made during 1906 and is well defined between gage heights 3.5 feet and 6.0 feet. Below gage height 3.5 feet the table is only fair.

Monthly discharge of Clark Fork at Missoula, Mont., for 1906.

[Drainage area, 5,960 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
February 20-28	1,500	810	1,060	18,900	0.178	0.06
March [a]	3,060	810	1,480	91,000	.248	.29
April	4,460	1,590	2,560	152,000	.430	.48
May	6,490	3,360	4,510	277,000	.757	.87
June	7,490	3,570	5,510	328,000	.924	1.03
July	3,780	1,220	2,060	127,000	.346	.40
August	1,500	915	1,170	71,900	.196	.23
September	1,460	915	1,100	65,500	.185	.21
October	1,440	990	1,150	70,700	.193	.22
November	4,900	1,330	2,360	140,000	.396	.44
December	2,120	1,620	1,920	118,000	.322	.37
The period				1,460,000		

[a] Open channel rating applied March 10 to 24.

NOTE.—Values are rated as follows: February, March, and August to December, fair; April to July, good.

STILLWATER RIVER NEAR KALISPELL, MONT.

Stillwater River rises in the northern part of Flathead County and flows southeast through several lakes into Flathead River.

The gaging station was established September 25, 1906. The gage is located at the Reiter wagon bridge, 2 miles from Kalispell. The flow is controlled by dams above. The measuring section is below the mouth of Whitefish River and includes the flow of that stream. The intake for the city waterworks is between the mouth of Whitefish and the gage. Owing to the extreme sluggishness of the Stillwater above the mouth of the Whitefish, it is impossible to make measurements; hence the flow of the former is obtained by subtracting the flow at the Whitefish station from that at this station. This gives the amount available for irrigation.

Discharge measurements are made from the bridge or may be made by wading at low stage.

The gage, which is read morning and evening by W. H. Reiter, is a staff, fastened to the upstream end of the bridge pier. The bench mark is a spike in the piling which is the upstream edge of the pier on which the right end of the right truss rests; it is 3 feet above the ground and is driven horizontally; elevation, 4.74 feet above gage datum.

Discharge measurements of Stillwater River near Kalispell, Mont., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
September 25	Follansbee and Wade	90	305	1.64	142
October 2	Follansbee and Richards	98	309	1.52	125
November 22[a]	R. Richards	67	107	2.12	322

[a] Measured by wading.

Daily gage height, in feet, of Stillwater River near Kalispell, Mont., for 1906.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1		1.95	1.50	2.58	12		1.95	1.70	1.70	23		1.85	1.75	2.10
2		1.80	2.02	2.50	13		1.41	1.75	1.95	24		1.82	1.65	1.80
3		2.10	2.20	2.50	14		1.21	1.85	2.32	25	1.65	1.35	2.30	1.68
4		1.85	1.45	2.42	15		1.71	2.05	2.28	26	1.60	1.92	2.75	2.05
5		1.70	2.00	2.45	16		1.70	3.25	2.28	27	1.72	2.22	2.70	1.55
6		1.68	2.05	2.40	17		1.56	3.05	2.28	28	1.95	2.15	2.65	1.95
7		1.56	1.70	1.98	18		1.56	2.95	2.30	29	2.32	1.95	2.62	1.70
8		1.31	1.60	1.75	19		1.60	2.32	2.25	30	2.40	1.38	2.58	1.70
9		1.90	1.35	1.72	20		1.51	2.02	2.25	31		1.98		1.58
10		1.86	2.00	1.70	21		1.28	2.00	2.20					
11		1.60	1.90	1.70	22		1.15	2.00	2.20					

NOTE.—The flow of this stream is controlled by dams.

Rating table for Stillwater River near Kalispell, Mont., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.10	67	1.60	140	2.10	310	2.60	670	3.10	1,200
1.20	77	1.70	163	2.20	370	2.70	760	3.20	1,320
1.30	89	1.80	190	2.30	430	2.80	860	3.30	1,450
1.40	104	1.90	220	2.40	500	2.90	970		
1.50	120	2.00	260	2.50	580	3.00	1,080		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 3 discharge measurements made during 1906.

Monthly discharge of Stillwater River near Kalispell, Mont., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
September 25-30	500	140	274	3,260
October	382	72	178	10,900
November	1,380	95	410	24,400
December	658	136	327	20,100
The period				58,660

NOTE.—Values are rated as follows: September, October, and December, good; November, fair.

WHITEFISH RIVER NEAR KALISPELL, MONT.

Whitefish River rises in the central part of Flathead County and flows south into Stillwater River above the gaging station on that stream.

The gaging station was established September 24, 1906. It is located at the Tetrault wagon bridge 10 miles from Kalispell and 6 miles from Columbia Falls. There is a dam at the outlet of the lake which feeds the river, and consequently the flow is wholly controlled.

The channel is straight for 500 feet above, and 200 feet below the station. The banks are high and are not likely to overflow. The bed of the stream is composed of gravel and is permanent. There is one channel at all stages.

Discharge measurements are made from the wagon bridge or may be made by wading at low stage.

The gage, which is read daily by F. R. Miles, is a staff fastened to timber abutment 200 feet upstream from the bridge, on the left bank. The bench mark is a black paint spot on a bowlder on the right bank, near the water's edge and directly downstream from old timber abutment; it is marked "U. S. G. S. B. M."; elevation, 3.02 feet above the gage datum.

Discharge measurements of Whitefish River near Kalispell, Mont., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
September 24[a]	Wade and Follansbee	106	99.7	2.28	126
October 22[b]	Follansbee and Richards	26	19.1	1.35	14.8
November 22[b]	R. Richards	32	25.0	1.70	15.9

[a] Made at bridge. [b] Made by wading.

Daily gage height, in feet, of Whitefish River near Kalispell, Mont., for 1906.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1		2.95	8		1.6	17	2.0		24	2.5	
2		2.95	11	1.4		18	2.0		25	2.6	
3		2.9	12	1.4		19	2.2		26	2.6	
4		2.85	13	1.4		20	2.3		27	2.8	
5		2.8	14	1.4		21	2.4		28	3.0	
6		2.65	15	1.6		22	2.4		29	3.0	
7		1.65	16	1.9		23	2.4		30	3.0	

CROW CREEK NEAR RONAN, MONT.

Crow Creek rises on the western slope of the Mission Range and flows westward across the Flathead Reservation, emptying into Clark Fork.

The gaging station was established September 21, 1906. It is located at the highway bridge on the stage road from St. Ignatius to Ronan, 4 miles south of Ronan. The station is several miles below the canyon.

The channel curves sharply to the right immediately above the station, but is straight for 200 feet below. The banks slope back gradually from the water's edge. At all stages except extreme flood the water will all pass beneath the bridge. The current is sluggish. The bed of the stream is composed of fine gravel.

Discharge measurements are made by wading at a section either above or below the bridge. At high stages measurements may be made at the bridge.

The gage, which is read morning and evening by Mrs. Alphonsine McIntyre, is a staff fastened to the upstream end of the bridge pier. The bench mark is a spike driven horizontally 2 feet above the ground, in the northeast corner of a log building, 50 feet downstream from the gage, on the left bank; elevation, 10 feet above the datum of the gage.

Discharge measurements of Crow Creek near Ronan, Mont., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
September 20[a].	Wade and Follansbee	33	56.5	1.00	24.9
October 18[b]	Follansbee and Richards	28	28.9	1.15	35.7
November 19[b].	R. Richards	28	39.0	1.86	73.8

[a] Made at bridge. [b] Made by wading.

Daily gage height, in feet, of Crow Creek River near Ronan, Mont., for 1906.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1		0.9	1.0	1.25	12		1.0	1.3	1.0	22	1.0	1.0	1.5	1.1
2		.9	1.0	1.2	13		1.05	1.6	1.0	23	.95	1.0	1.45	1.05
3		1.2	1.0	1.15	14		1.0	1.8	1.05	24	.9	1.0	1.4	......
4		1.15	1.0	1.15	15		1.0	2.2	1.15	25	.9	1.0	1.4	......
5		1.0	1.0	1.15	16		1.1	2.95	1.05	26	.9	1.15	1.25	1.6
6		1.0	1.0	1.1	17		1.15	2.2	1.0	27	.9	1.3	1.1	1.4
7		1.0	1.0	1.05	18		1.2	2.0	1.0	28	1.0	1.2	1.2	1.35
8		1.0	1.3	1.1	19		1.1	1.9	1.0	29	.95	1.2	1.2	1.3
9		1.0	1.3	1.1	20		1.05	1.8	1.0	30	.9	1.1	1.2	1.3
10		1.0	1.3	1.0	21	1.0	1.0	1.6	1.0	31	......	1.1	......	1.2
11		1.0	1.3	1.0										

Rating table for Crow Creek near Ronan, Mont., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.90	22	1.40	48	1.80	71	2.20	96	2.60	126
1.00	27	1.50	53	1.90	76	2.30	103	2.70	134
1.10	32	1.60	59	2.00	82	2.40	110	2.80	143
1.20	37	1.70	65	2.10	89	2.50	118	2.90	152
1.30	42								

NOTE.—The above table is applicable only for open-channel conditions. It is based on 3 discharge measurements made during 1906 and is not well defined.

Monthly discharge of Crow Creek near Ronan, Mont., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
September 21-30	27	22	23.9	474
October	42	22	29.9	1,840
November	156	27	51.5	3,060
December	59	27	34.2	2,100
The period				7,470

NOTE.—Values are only approximate on account of the small number of measurements.

MISSION CREEK NEAR ST. IGNATIUS, MONT.

Mission Creek rises on the western slope of the Mission Range and flows across the Flathead Reservation into Clark Fork.

The station was established September 21, 1906. It is located opposite the home of A. A. Booke, 1 mile downstream from St. Ignatius. There are a few small ditches diverting water above the gage.

The channel curves both above and below the station. The right bank is low and liable to overflow; the left is high and will not overflow. The current is swift. The bed is composed of gravel and is permanent. There is one channel at all stages.

Discharge measurements are made from the footbridge to which the staff gage is attached. The gage, which is 6 or 8 miles below the canyon, is read morning and evening by Mrs. A. A. Booke. The bench mark is a large spike driven horizontally in a pine tree 27 feet back of the gage on the left bank, below a blaze in the tree and 1 foot above the ground; elevation, 7.05 feet above the gage datum.

Discharge measurements of Mission Creek near St. Ignatius, Mont., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
September 21	Wade and Follansbee	30	25.8	0.78	65.4
October 17	Follansbee and Richards	29	25.9	.76	56.5
November 19	R. Richards	28	21.5	.66	46.5

Daily gage height, in feet, of Mission Creek near St. Ignatius, Mont., for 1906.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1		0.7	0.7	0.5	12		0.7	0.65	0.55	23	0.75	0.65	0.65	0.55
2		.7	.7	.55	13		.7	.7	.55	24	.75	.65	.6	.55
3		.7	.7	.55	14		.7	.75	.55	25	.7	.65	.6	.6
4		.7	.7	.55	15		.7	.82	.55	26	.7	.68	.6	.6
5		.7	.7	.55	16		.7	.82	.55	27	.7	.72	.6	.6
6		.7	.68	.55	17		.72	.72	.55	28	.7	.75	.58	.6
7		.7	.75	.55	18		.72	.7	.55	29	.7	.75	.55	6
8		.7	.7	.55	19		.72	.65	.55	30	.7	.7	.52	.55
9		.75	.7	.55	20		.7	.7	.55	31		.7		.55
10		.7	.65	.55	21	0.8	7	.65	.55					
11		.7	.65	.55	22	.8	.7	.65	.55					

Rating table for Mission Creek near St. Ignatius, Mont., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.50	33	0.60	40	0.70	50	0.80	65	0.90	85

NOTE.—The above table is applicable only for open-channel conditions. It is based on 3 discharge measurements made during 1906 and is not well defined.

Monthly discharge of Mission Creek near St. Ignatius, Mont., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
September 21–30	65	50	54.4	1,080
October	57	45	50.5	3,110
November	69	34	48.1	2,860
December	40	33	36.5	2,240
The period				9,290

NOTE.—Values are only fair on account of the small number of measurements.

POST CREEK NEAR ST. IGNATIUS, MONT.

Post Creek rises on the western slope of the Mission Range and flows across Flathead Reservation into Mission Creek, a tributary of Clark Fork.

The gaging station was established September 21, 1906. It is located at the upper highway bridge, near the home of Joseph Allard, 10 miles north of St. Ignatius. The station is near the canyon and only two small ditches divert above. Because of the storage possibilities of McDonald Lake, the source of Post Creek, and also because of the land which can be reached, this station is very important.

The channel is straight for 25 feet above and 100 feet below the gage. The current is very swift. Both banks are wooded and will not overflow. The bed of the stream is composed of gravel and small bowlders and is permanent. There is one channel at all stages.

Discharge measurements are made from the downstream side of the highway bridge.

The gage, which is read twice each day by Mrs. Adaline Allard, is a staff fastened to the overhanging stump at the right end of the bridge. The bench mark is a headless spike, 2 feet above the ground, in a blaze in a pine tree 2 feet in diameter, 45 feet from the left bank and 18 feet from the road; elevation, 8.90 feet above the gage datum.

Discharge measurements of Post Creek near St. Ignatius, Mont., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
September 21	Grover and Follansbee	22	24.0	1.50	63.2
October 17	Follansbee and Richards	22	23.4	1.51	58.8
November 19	R. Richards	25	29.6	1.73	70.7

Daily gage height, in feet, of Post Creek near St. Ignatius, Mont., for 1906.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1	......	1.4	1.5	1.4	12	......	1.5	1.8	1.3	22	1.5	1.4	1.7	1.3
2	......	1.4	1.4	1.4	13	......	1.4	1.8	1.3	23	1.4	1.4	1.65	1.3
3	......	1.3	1.4	1.3	14	......	[a]1.4	1.9	1.3	24	1.5	1.4	1.55	1.3
4	......	1.4	1.4	1.3	15	......	[a]1.4	2.0	1.3	25	1.5	1.4	1.5	1.3
5	......	1.5	1.5	1.3	16	......	[a]1.5	2.0	1.3	26	[a]1.5	1.4	1.5	1.3
6	......	1.4	1.5	1.3	17	......	1.5	1.9	1.3	27	1.5	1.4	1.45	1.3
7	......	1.4	1.5	1.3	18	......	1.5	1.8	1.3	28	1.4	1.4	1.4	1.3
8	......	1.4	1.6	1.3	19	......	1.6	1.7	1.3	29	1.4	1.4	1.4	1.3
9	......	1.4	1.6	1.3	20	......	1.5	1.7	1.3	30	1.4	1.5	1.4	1.3
10	......	1.4	1.7	1.3	21	1.5	1.4	1.7	1.3	31	......	1.5	......	1.3
11	......	1.4	1.7	1.3										

[a] Interpolated.

Rating table for Post Creek near St. Ignatius, Mont., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.30	50	1.50	59	1.70	69	1.90	81	2.00	88
1.40	54	1.60	64	1.80	75				

NOTE.—The above table is applicable only for open-channel conditions. It is based on 3 discharge measurements made during 1906 and is not well defined.

Monthly discharge of Post Creek near St. Ignatius, Mont., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
September 21-30	59	54	57.0	1,130
October	64	50	55.5	3,410
November	88	54	65.5	3,900
December	54	50	50.3	3,090
The period				11,530

NOTE.—Values are only fair on account of the small number of measurements.

JOCKO RIVER AT RAVALLI, MONT.

Jocko River rises in the southeastern part of Flathead Reservation and flows northwest into Clark Fork.

The gaging station, which was established October 18, 1906, is located 400 feet downstream from a point opposite the railroad station at Ravalli.

The channel is straight for several hundred feet above and below the gage. Both banks are sparsely wooded and will not overflow except at very high stage. The current is swift, and small rapids occur a short distance below the gage. The bed of the stream is composed of gravel and small bowlders and is permanent. There is one channel at all stages.

Discharge measurements may be made from the highway bridge 1 mile upstream, or preferably by wading at or near the gage. In high water the bridge must be used.

The gage, which is read daily by H. F. Lynn, the station agent, is a staff fastened to an overhanging tree on the right bank. The bench mark is a nail 2 feet above the ground in a tree 25 feet northeast of the gage; elevation, 6.80 feet above the datum of the gage.

Discharge measurements of Jocko River at Ravalli, Mont., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
October 18[a]	Follansbee and Richards	46	80	1.69	150
November 20[b]	R. Richards	67	120	2.14	317

[a] Measured at bridge.

[b] Measured by wading at gage.

Daily gage height, in feet, of Jocko River at Ravalli, Mont., for 1906.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1	......	1.75	......	12	......	1.8	1.85	22	1.65	1.85	1.8
2	......	1.75	1.8	13	......	2.1	1.8	23	1.65	1.85	1.8
3	......	1.7	1.8	14	......	2.15	1.8	24	1.65	1.85	1.8
4	......	1.7	1.8	15	......	2.75	1.8	25	1.65	1.85	1.8
5	......	1.7	1.8	16	......	2.7	1.8	26	2.0	1.85	1.85
6	......	1.7	1.8	17	......	2.5	1.8	27	2.1	1.8	1.9
7	......	1.7	1.85	18	1.65	2.3	1.8	28	1.95	1.8	1.9
8	......	1.85	1.8	19	1.65	2.1	1.75	29	1.9	1.8	1.85
9	......	1.8	1.8	20	1.65	1.95	1.8	30	1.8	1.8	......
10	......	1.8	1.8	21	1.65	1.9	1.8	31	1.8	......	......
11	......	1.8	1.85								

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made in Clark Fork drainage basin in 1906:

Miscellaneous measurements in Clark Fork drainage basin.

Date.	Stream.	Locality.	Width.	Area of section.	Gage height.	Discharge.
			Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
September 20	Mud Creek	Highway bridge near Ronan, Mont.	8	4.5	1.51	2.55
September 25	South Fork of Flathead River.	Columbia Falls, Mont	195	312	....	649

SPOKANE RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Spokane River has its source in Lake Coeur d'Alene, Idaho, flows westward through Washington for about 120 miles, and empties into Columbia River. Its drainage area consists of rough mountainous land, more or less timbered, interspersed here and there with valleys or level table-lands of tillable areas.

The rainfall in this basin is approximately 20 inches per annum, and the region is semiarid. The principal tributary streams are Hangman Creek, Little Spokane, and Chamokane rivers.

The waters of the streams are largely used for irrigation, power, and municipal water supply. The city of Spokane is furnished with an abundance of electric power from plants at Spokane, Wash., and Post Falls, Idaho. The waters of Little Spokane River are in great demand for irrigation development.

SPOKANE RIVER AT SPOKANE, WASH.

This gaging station was originally established October 17, 1896, on the Oregon Railroad and Navigation Company's wooden bridge, about 1 mile above the falls, where discharge measurements and gage readings were taken until July 8, 1903, the gage datum being 1,880 feet above sea level by city datum and 1,865 feet by Government datum.

March 30, 1904, a cable station was established about one-half mile above the Mission Street Bridge, or 1 mile above the former station at the Oregon Railroad and Navigation Company's bridge. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 25, where are given also references to publications that contain data for previous years.

The following measurement was made October 1, 1906:

Width, 195 feet; area, 1,630 square feet; gage height, 1.28 feet; discharge, 1,330 second-feet.

Daily gage height, in feet, of Spokane River at Spokane, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.16	2.83	5.40	5.63	8.91	6.31	4.16	2.15	1.64	1.40	1.81	3.27
2	2.16	2.96	5.38	6.10	8.81	6.37	4.07	2.10	1.70	1.59	1.84	3.24
3	2.14	3.10	5.32	6.36	8.71	6.41	3.96	2.09	1.54	1.52	1.90	3.20
4	2.13	3.21	5.24	6.62	8.60	6.41	3.87	2.14	1.53	1.46	1.67	3.15
5	2.00	3.32	5.20	6.77	8.60	6.37	3.81	1.73	1.63	1.49	1.53	3.28
6	2.03	3.50	5.12	6.80	8.51	6.31	3.72	1.80	1.59	1.54	1.82	[a]3.90
7	2.26	3.49	5.04	6.90	8.37	6.23	3.66	1.92	1.58	1.60	1.76	3.65
8	2.17	3.80	4.98	7.09	8.22	6.16	3.59	1.95	1.63	1.35	1.97	3.61
9	2.19	3.79	4.96	7.30	8.05	6.12	3.53	2.05	1.85	1.55	2.05	3.74
10	2.17	3.74	4.95	7.55	7.90	5.98	3.38	1.78	1.60	1.47	2.07	3.76
11	2.18	3.75	4.93	7.78	7.77	5.92	3.29	1.76	1.63	1.46	1.93	4.00
12	2.19	3.74	4.91	7.90	7.71	5.82	3.16	1.73	1.65	1.51	1.70	3.65
13	2.21	3.72	4.90	7.97	7.68	5.80	3.06	1.73	1.56	1.45	1.94	3.43
14	2.22	3.56	4.86	8.00	7.60	5.73	2.96	1.76	1.50	1.56	1.80	3.49
15	2.24	3.40	4.83	7.93	7.55	5.62	2.92	1.80	1.56	1.35	1.90	3.46
16	2.23	3.37	4.82	7.91	7.44	5.51	2.89	1.84	1.53	1.63	2.91	3.43
17	2.25	3.32	4.70	7.92	7.32	5.41	2.83	1.91	1.50	1.53	2.67	3.38
18	2.24	3.34	4.60	8.02	7.18	5.32	2.85	1.75	1.58	1.70	3.03	3.44
19	2.24	3.38	4.52	8.08	7.00	5.21	2.65	1.56	1.67	1.65	[a]4.59	3.38
20	2.21	3.70	4.45	8.11	6.85	5.11	2.73	1.77	1.62	1.71	3.72	3.45
21	2.21	4.11	4.37	8.31	6.70	5.01	2.58	1.76	1.43	1.70	4.20	3.43
22	2.22	4.47	4.31	8.33	6.55	4.93	2.50	1.95	1.43	1.63	4.56	3.50
23	2.24	4.74	4.22	8.48	6.46	4.83	2.47	1.76	1.42	1.65	3.90	3.48
24	2.26	4.97	4.18	8.80	6.35	4.74	2.49	1.63	1.40	1.63	4.03	3.51
25	2.29	5.10	4.18	9.18	6.25	4.64	2.38	1.64	1.65	1.68	4.06	3.92
26	2.36	5.24	4.24	9.23	6.02	4.52	2.34	1.70	1.53	1.66	4.07	4.20
27	2.47	5.33	4.35	9.31	6.04	4.45	2.25	1.63	1.57	1.62	4.05	4.55
28	2.62	5.39	4.60	9.22	6.03	4.36	2.26	1.76	1.57	1.81	4.01	5.00
29	2.67	....	4.80	9.11	5.94	4.32	2.18	1.65	1.62	1.54	3.91	5.50
30	2.73	....	5.03	9.04	6.00	4.25	2.26	1.68	1.60	1.70	3.81	5.65
31	2.78	....	5.30	....	6.05	....	2.21	1.60	....	1.73	....	5.70

[a] Backwater due to log jams.

NOTE.—The river at this point does not freeze on account of the underground flow of water which comes through the gravel above the station and into the river again.

Rating table for Spokane River at Spokane, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.00	1,000	2.10	2,340	3.20	4,080	4.60	6,660	6.80	11,340
1.10	1,100	2.20	2,490	3.30	4,250	4.80	7,050	7.00	11,830
1.20	1,200	2.30	2,640	3.40	4,420	5.00	7,450	8.00	14,490
1.30	1,300	2.40	2,790	3.50	4,600	5.20	7,850	9.00	17,380
1.40	1,410	2.50	2,940	3.60	4,780	5.40	8,250	10.00	20,580
1.50	1,520	2.60	3,100	3.70	4,960	5.60	8,660	11.00	23,980
1.60	1,640	2.70	3,260	3.80	5,140	5.80	9,080	12.00	27,580
1.70	1,760	2.80	3,420	3.90	5,330	6.00	9,510		
1.80	1,900	2.90	3,580	4.00	5,520	6.20	9,950		
1.90	2,040	3.00	3,740	4.20	5,900	6.40	10,400		
2.00	2,190	3.10	3,910	4.40	6,280	6.60	10,860		

NOTE.—The above table is based on 22 discharge measurements made during 1904-1907 and is well defined between gage heights 1.4 feet and 12.0 feet.

Monthly discharge of Spokane River at Spokane, Wash., for 1906.

[Drainage area, 4,000 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	3,390	2,190	2,600	160,000	0.650	0.75
February	8,230	3,470	5,320	295,000	1.33	1.38
March	8,250	5,860	7,050	433,000	1.76	2.03
April	18,400	8,720	14,200	845,000	3.55	3.96
May	17,100	9,380	12,800	787,000	3.20	3.69
June	10,400	6,000	8,440	502,000	2.11	2.35
July	5,820	2,460	3,790	233,000	.948	1.09
August	2,420	1,590	1,920	118,000	.480	.55
September	1,970	1,410	1,610	95,800	.402	.45
October	1,910	1,360	1,620	99,600	.405	.47
November	6,640	1,560	3,600	214,000	.900	1.00
December	8,870	4,000	5,210	320,000	1.30	1.50
The year	18,400	1,360	5,680	4,100,000	1.42	19.22

NOTE.—Values are rated as excellent.

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made in Spokane River drainage basin in 1906:

Spokane River.—A measurement was made at low water October 1, 1906, at Spokane Bridge, near the Idaho-Washington State line.

Width, 163 feet; area, 778 square feet; discharge, 803 second-feet.

A measurement was made at medium stage November 12, 1906, in sec. 24, T. 27 N., R. 39 E.

Width, 154 feet; area, 760 square feet; discharge, 2,500 second-feet.

OKANOGAN RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Okanogan River rises in Okanogan Lake, in British Columbia, and flows southward, entering Columbia River near Brewster, Wash. Its course in Canada lies through a series of narrow lakes. The drainage area is comparatively rough and mountainous, and is timbered except along the river. The rainfall is approximately 20 inches per annum. The principal tributaries in the United States are Similkameen and Conconully rivers and Antwine, Bonaparte, Salmon, and Johnson creeks.

The main stream is navigable from Brewster to Riverside except during low-water periods, while the tributaries are used largely for irrigation.

SALMON CREEK NEAR MALOTT, WASH.

This station was established April 11, 1903. It is located opposite R. D. Jones's house, on the county road halfway between Malott and Conconully, Okanogan County. It is reached by way of the Great Northern Railway to Wenache, thence by way of the Columbia River steamers to Brewster, and by the Conconully stage from Brewster to Jones's ranch. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 32, where are given also references to publications that contain data for previous years.

Daily gage height, in feet, of Salmon Creek near Malott, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.69	0.75	0.70	1.52	1.42	2.21	1.46	0.92	0.49	0.54	0.69	0.71
2	.68	.74	.69	1.33	1.38	2.02	1.40	.88	.46	.56	.69	.69
3	.67	.73	.68	1.25	1.44	2.00	1.33	.83	.46	.54	.71	.71
4	.69	.70	.66	1.29	1.33	2.29	1.29	.83	.44	.54	.83	.67
5	.70	.70	.68	1.40	1.25	2.00	1.25	.81	.44	.58	1.00	.67
6	.71	.69	.73	1.50	1.23	2.00	1.23	.81	.44	.54	.96	.67
7	.70	.70	.72	1.54	1.19	1.96	1.27	.79	.44	.56	.83	.69
8	.71	.65	.74	1.33	1.19	1.83	1.14	.75	.46	.60	.75	.67
9	.73	.65	.75	1.25	1.21	1.79	1.12	.75	.50	.56	.75	.71
10	.70	.58	.75	1.10	1.21	1.83	1.08	.75	.50	.54	.81	.73
11	.71	.60	.70	1.14	1.25	1.96	.98	.71	.57	.56	.79	.71
12	.71	.58	.68	1.11	1.25	2.12	1.00	.67	.54	.67	.79	.67
13	.73	.56	.70	1.12	1.29	2.02	.99	.67	.58	.67	.75	.69
14	.73	.58	.73	1.17	1.33	2.00	.92	.71	.60	.67	.81	.67
15	.70	.64	.70	1.21	1.77	1.96	.90	.67	.62	.69	1.38	.67
16	.69	.66	.70	1.31	1.41	1.83	.88	.66	.64	.73	1.12	.69
17	.67	.68	.66	1.31	1.29	1.83	.83	.58	.58	.67	.90	.69
18	.67	.66	.66	1.25	1.27	1.79	1.05	.56	.58	.67	.83	.71
19	.69	.70	.70	1.25	1.25	1.71	1.00	.54	.56	.64	.83	.71
20	.70	.75	.66	1.33	1.31	1.67	1.00	.52	.58	.67	.79	.73
21	.71	.75	.70	1.44	1.29	1.62	1.05	.54	.56	.62	.83	.71
22	.71	.87	.70	1.56	1.40	1.58	1.35	.58	.54	.67	.79	.73
23	.73	.77	.75	1.52	1.46	1.54	1.31	.66	.54	.67	.79	.73
24	.72	.75	.83	1.43	1.35	1.52	1.25	.58	.54	.67	.75	.67
25	.73	.73	.87	1.29	1.32	1.50	1.12	.56	.56	.67	.77	.67
26	.73	.75	.87	1.29	2.42	1.47	1.05	.56	.54	.67	.75	.54
27	.74	.73	.85	1.29	2.75	1.58	1.00	.54	.54	.71	.75	.46
28	.75	.70	.83	1.33	2.35	1.71	1.00	.54	.54	.69	.75	.50
29	.75	....	.82	1.33	2.10	1.54	.96	.52	.56	.67	.75	.71
30	.73	....	.86	1.35	2.08	1.46	.94	.50	.54	.67	.73	.67
31	.73	....	1.42	....	2.12	....	.92	.50	....	.67	....	.67

Note.—The creek never freezes at the gage.

JOHNSON CREEK NEAR RIVERSIDE, WASH.

This station was established May 30, 1903. The weir was destroyed July 30, 1904, and the station discontinued, but it was replaced April 30, 1905, and the records resumed. It is located at

Sogle's ranch, on the road from Riverside to Conconully, 1 mile from Riverside and 17 miles from Conconully.

The right bank of the stream is low for 10 feet back from the water's edge and then it rises more abruptly. The left bank is steep and rocky. The bed of the creek is composed of small gravel.

The equipment consists of a sharp-crested weir with an 8-foot opening and vertical sides. Below the level of the crest the weir consists of two 2-inch pine planks, 12 inches wide, securely spiked together. Above the crest on each end are two planks 12 inches wide, which form the ends of the weir. The edges of the crest and ends are one-fourth inch wide and beveled on the downstream side to an angle of 60°. The pool above the weir is 10 feet long, 10 to 15 feet wide, and 1 foot deep below the crest. The water has a fall of about 1 foot after passing the weir and then flows rapidly away.

The depth of the water on the crest is determined by a hook gage and vernier reading to thousandths of a foot. The zero on the gage is 0.10 foot above the crest of the weir. During 1905 and 1906 the gage readings were made once each day by Mrs. S. Sogle. The bench mark is the top of the fence opposite the weir; elevation, 12.91 feet above zero of the gage and 1,241.54 feet above sea level.

A description of this station, with discharge data, is contained in Water-Supply Papers Nos. 100 and 135, United States Geological Survey.

Daily discharge, in second-feet, of Johnson Creek at Riverside, Wash., for 1905–6.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1					11.7	6.3	10.8	6.2	6.1	8.3	8.0	9.5
2					11.6	6.3	10.4	6.7	6.2	8.3	8.0	11.3
3					11.4	9.0	9.9	6.3	6.4	7.6	8.0	11.4
4					11.1	10.4	8.8	6.2	5.8	7.4	7.9	11.5
5					11.0	9.1	8.1	6.1	6.1	8.1	7.9	7.9
6					10.7	8.8	6.8	6.0	5.9	8.7	7.9	7.9
7					10.7	8.9	6.5	5.8	5.9	9.3	7.9	8.0
8					10.6	8.7	6.5	5.6	6.0	8.1	8.0	7.9
9					11.1	8.1	5.6	5.4	6.4	7.5	8.0	8.4
10					10.8	8.0	5.6	5.4	6.2	7.3	8.1	8.5
11					10.7	9.5	4.6	6.1	6.1	7.2	8.1	8.4
12					9.7	8.3	5.1	5.8	6.1	7.1	8.0	8.4
13					9.5	7.6	5.0	5.8	8.3	6.9	8.1	8.4
14					6.8	7.1	6.6	5.6	8.5	6.8	8.3	8.0
15					6.1	6.9	6.6	5.8	6.9	7.8	8.3	8.9
16					7.7	6.9	4.6	6.0	7.0	7.4	8.4	8.3
17					7.7	6.8	6.8	6.2	7.6	7.4	8.4	8.3
18					6.4	6.8	7.6	6.2	7.4	7.5	8.4	8.7
19					5.9	6.8	6.4	6.1	7.0	7.9	12.5	9.0
20					6.2	6.7	5.0	5.8	7.2	7.9	12.1	8.8
21					6.7	6.6	5.3	5.6	7.3	7.9	9.7	8.7
22					7.1	6.8	5.1	5.4	7.1	7.9	8.8	8.0
23					9.5	6.6	5.1	5.4	6.3	8.0	8.7	7.6
24					9.6	7.3	5.1	5.6	6.3	8.1	8.6	9.0
25					7.1	9.0	5.1	6.5	6.3	7.9	8.7	8.4
26					8.1	9.5	5.1	6.6	7.3	7.9	8.7	8.4
27					7.2	13.6	5.4	6.7	12.5	7.9	8.3	8.1
28					7.2	12.2	6.0	6.7	12.3	7.9	7.9	8.0
29					7.1	11.5	7.0	6.4	9.1	8.0	7.9	7.9
30					4.6	10.8	6.6	5.7	8.0	8.0	9.2	7.9
31					6.1		6.2	6.0		8.0		8.8

Daily discharge, in second-feet, of Johnson Creek at Riverside, Wash., for 1905-6—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
1	4.6	10.1	9.6	12.2	3.7	6.4	3.0	1.0	3.5	4.1	4.8	6.1
2	8.3	9.8	9.5	9.8	3.3	5.9	3.2	1.3	3.4	4.1	4.9	6.3
3	8.1	9.7	9.5	9.1	2.8	4.8	2.4	1.3	3.1	4.2	5.1	6.4
4	7.9	9.5	9.6	8.8	2.8	6.8	2.4	1.0	3.0	4.2	6.8	6.4
5	7.9	9.2	9.5	8.7	1.8	6.1	4.1	1.0	2.6	4.3	8.1	6.6
6	7.9	8.5	9.5	8.6	2.1	5.8	3.0	1.9	2.8	4.4	5.7	7.3
7	6.3	8.9	9.5	8.5	2.3	5.6	3.1	1.3	2.8	4.6	5.6	7.1
8	8.1	8.5	9.5	8.5	1.9	5.3	3.0	1.4	3.1	4.2	5.7	6.9
9	8.2	8.4	9.2	8.4	2.8	5.3	1.6	1.4	3.1	4.2	6.0	6.6
10	7.9	8.3	9.0	8.4	2.7	4.9	1.6	1.3	3.1	4.2	6.8	6.5
11	14.1	8.3	8.1	8.3	3.5	5.1	1.5	1.4	3.2	4.3	6.8	6.9
12	8.4	8.2	7.7	8.4	3.4	5.8	1.3	1.4	3.4	4.4	5.7	6.8
13	8.6	8.3	8.8	8.4	3.0	5.4	1.3	1.4	4.6	4.4	5.9	6.6
14	8.5	8.1	8.3	8.4	2.9	5.6	1.3	1.9	4.9	4.6	8.4	6.6
15	8.0	8.6	7.6	8.3	5.7	5.7	1.3	1.7	4.9	4.4	7.3	5.6
16	8.2	8.8	9.5	8.3	4.5	6.8	1.3	1.6	4.4	4.5	7.3	5.5
17	8.0	10.4	8.7	8.1	4.5	6.2	1.4	1.4	4.1	4.5	6.6	6.7
18	8.1	12.5	8.5	8.0	3.9	5.6	3.1	1.4	4.4	4.4	6.4	8.5
19	33.6	17.5	8.2	8.0	3.5	5.2	3.3	1.7	4.2	4.4	6.0	7.9
20	10.1	13.8	8.5	8.0	3.4	5.2	2.4	1.7	4.3	4.5	6.1	7.3
21	7.6	15.8	8.7	8.0	1.9	5.0	2.2	1.7	4.2	4.6	6.1	7.2
22	7.9	13.2	8.8	7.6	2.0	4.8	2.8	2.2	4.2	4.5	6.2	7.4
23	9.2	11.3	8.8	7.9	3.3	4.7	2.7	2.6	4.2	4.5	6.1	7.3
24	10.1	10.7	9.2	7.9	3.7	4.7	2.6	2.6	4.4	4.6	6.0	7.2
25	10.1	12.2	9.0	8.0	3.9	4.2	2.2	2.4	4.4	4.6	6.0	7.2
26	10.0	10.8	8.7	7.3	3.8	3.1	1.5	3.2	4.3	4.6	6.1	7.1
27	9.5	11.3	8.7	7.1	9.8	4.3	1.3	3.8	4.4	4.6	5.8	7.0
28	9.1	10.1	8.7	6.6	8.8	4.3	1.4	2.6	4.1	4.6	6.1	7.3
29	9.2	....	8.7	5.7	7.1	3.5	1.0	2.6	4.1	4.5	6.1	7.3
30	9.4	....	9.0	5.6	4.9	3.2	1.0	3.0	4.1	4.8	6.0	7.1
31	9.6	....	13.0	....	6.6	....	1.4	3.2	....	4.7	....	3.4

NOTE.—These discharges were obtained from the Cippoletti weir formula, using the gage heights corrected to give the head on crest of weir.

Monthly discharge of Johnson Creek at Riverside, Wash., for 1905–6.

[Drainage area, 66 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.						
May	11.7	4.6	8.64	531	0.131	0.15
June	13.6	6.3	8.36	497	.127	.14
July	10.8	4.6	6.43	395	.097	.11
August	6.7	5.4	5.99	368	.091	.10
September	12.5	5.8	7.19	428	.109	.12
October	9.3	6.8	7.81	480	.118	.14
November	12.5	7.9	8.56	509	.130	.14
December	11.5	7.6	8.65	532	.131	.15
The period	....	....	....	3,740	....	....
1906.						
January	33.6	4.6	9.44	580	.143	.16
February	17.5	8.1	10.4	578	.158	.16
March	13.0	7.6	9.02	555	.137	.16
April	12.2	5.6	8.16	486	.124	.14
May	9.8	1.8	3.88	239	.059	.07
June	6.8	3.1	5.18	308	.078	.09
July	3.3	1.0	2.12	130	.032	.04
August	3.8	1.0	1.88	116	.028	.03
September	4.9	2.6	3.84	228	.058	.06
October	4.8	4.1	4.44	273	.067	.08
November	8.4	4.8	6.22	370	.094	.10
December	8.5	3.4	6.78	417	.103	.12
The year	33.6	1.0	5.95	4,280	.090	1.21

NOTE.—Values for 1905–6 are excellent.

METHOW RIVER DRAINAGE BASIN.

METHOW RIVER AT PATEROS, WASH.

Methow River heads on the eastern slope of the Cascade Range in northern Washington and flows southeast into the Columbia River. Its drainage area throughout is mountainous and heavily timbered. The rainfall varies from 40 inches at the headwaters to 20 inches near the mouth of the stream. The waters of the smaller tributaries are largely used for irrigation.

This station was originally established May 3, 1903, on a highway bridge about 1,000 feet above the mouth of the river; the first two measurements were taken from this bridge. During the summer of 1903 the bridge was washed away, and a temporary bridge 400 feet farther downstream was used in making the measurement of March 20, 1904. During the spring of 1904 this bridge also was abandoned because of its temporary nature and the poor section at this point, and a cable station was established about a mile above the mouth of the river. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 35, where are given also references to publications that contain data for previous years.

The following measurement was made December 29, 1906. There was a narrow strip of ice on each bank.

Width, 154 feet; area, 342 feet; gage height, 4.12 feet; discharge, 489 second-feet.

Daily gage height, in feet, of Methow River at Pateros, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.9	3.9	3.9	4.55	7.35	8.3	6.4	4.65	4.15	4.0	4.45	4.35
2	3.9	3.9	3.9	4.55	7.5	8.3	6.5	4.6	4.15	4.0	4.4	4.35
3	3.9	3.9	3.95	4.55	7.8	8.3	6.6	4.55	4.1	4.0	4.4	4.35
4	[a] 4.1	3.9	3.95	4.65	7.6	9.5	6.7	4.55	4.1	4.0	4.45	4.35
5	4.1	3.9	3.95	4.8	7.2	8.5	6.75	4.55	4.05	4.0	4.45	4.35
6	4.1	3.9	3.95	5.2	7.0	8.2	6.85	4.55	4.05	4.0	4.45	4.35
7	4.1	3.8	3.95	5.7	6.95	7.8	7.0	4.45	4.05	3.95	4.4	4.35
8	3.95	3.8	3.95	5.8	7.0	7.5	6.6	4.45	4.05	3.95	4.45	4.35
9	3.95	3.8	4.0	5.65	7.1	7.0	6.4	4.45	4.05	3.95	4.4	4.35
10	3.95	3.8	4.0	5.5	7.2	7.3	6.25	4.45	4.1	3.95	4.45	4.35
11	3.95	3.9	4.0	5.4	7.75	7.3	6.15	4.4	4.1	3.95	4.65	4.35
12	4.0	4.0	3.9	5.3	7.8	8.3	6.0	4.4	4.1	3.95	4.65	4.35
13	4.15	4.0	3.9	5.2	7.8	8.0	5.95	4.4	4.1	3.95	4.65	4.35
14	4.45	3.95	3.9	5.2	7.1	7.6	5.8	4.4	4.1	3.95	4.7	4.0
15	4.1	3.95	3.95	5.3	7.3	7.2	5.7	4.4	4.1	4.0	5.3	4.25
16	4.1	3.95	3.95	5.5	7.0	7.4	5.6	4.4	4.1	4.05	5.15	4.25
17	4.1	3.95	3.95	5.5	6.9	7.1	5.5	4.35	4.1	4.05	4.9	4.25
18	4.1	4.0	3.95	5.6	6.7	6.8	5.4	4.3	4.1	4.05	4.8	4.2
19	4.1	4.0	3.95	5.7	6.65	6.75	5.35	4.25	4.1	4.05	4.7	4.15
20	4.1	4.05	3.95	5.7	6.6	6.7	5.25	4.25	4.1	4.05	4.65	4.15
21	4.1	4.0	3.95	6.1	6.6	6.7	5.2	4.2	4.05	4.0	4.6	4.2
22	4.1	3.95	3.95	6.8	6.6	6.65	5.15	4.25	4.05	4.0	4.55	4.2
23	4.2	3.95	3.95	7.0	6.65	6.6	5.05	4.25	4.05	4.0	4.5	4.2
24	4.25	3.95	4.0	6.8	6.75	6.55	5.0	4.25	4.05	4.0	4.5	4.2
25	4.15	3.95	4.05	6.5	6.75	6.75	4.95	4.25	4.05	4.0	4.5	4.2
26	4.15	3.95	4.05	6.3	10.5	7.25	4.9	4.25	4.05	3.95	4.45	4.0
27	4.15	3.9	4.1	6.3	10.5	7.4	4.85	4.2	4.05	4.6	4.45	4.05
28	4.1	3.95	4.15	6.35	9.2	7.4	4.8	4.2	4.05	4.55	4.4	4.05
29	4.0	....	4.15	6.35	9.0	7.0	4.8	4.15	4.0	4.55	4.35	4.1
30	3.9	....	4.25	6.95	8.7	6.6	4.75	4.15	4.0	4.5	4.35	4.15
31	3.9	....	4.5	....	8.4	....	4.7	4.15	....	4.5	....	4.15

[a] Ice forming along banks, narrowing channel.

Rating table for Methow River at Pateros, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
3.80	400	4.80	902	5.80	1,988	6.80	3,560	8.60	7,088
3.90	420	4.90	984	5.90	2,128	6.90	3,738	8.80	7,506
4.00	450	5.00	1,072	6.00	2,272	7.00	3,920	9.00	7,930
4.10	486	5.10	1,166	6.10	2,420	7.20	4,294	9.20	8,356
4.20	528	5.20	1,266	6.20	2,572	7.40	4,676	9.40	8,785
4.30	576	5.30	1,372	6.30	2,726	7.60	5,066	9.60	9,215
4.40	630	5.40	1,484	6.40	2,884	7.80	5,460	9.80	9,646
4.50	690	5.50	1,602	6.50	3,050	8.00	5,860	10.00	10,080
4.60	756	5.60	1,724	6.60	3,216	8.20	6,264		
4.70	826	5.70	1,854	6.70	3,386	8.40	6,674		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903-1906 and is well defined.

Monthly discharge of Methow River at Pateros, Wash., for 1906.

[Drainage area, 1,710 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec-ft. per sq. mile.	Depth in inches.
January	660	420	478	29,400	0.28	0.32
February	468	400	430	23,900	.25	.26
March	690	420	455	28,000	.27	.31
April	3,920	723	1,970	117,000	1.15	1.28
May	11,200	3,220	5,040	310,000	2.95	3.40
June	9,000	3,130	4,770	284,000	2.79	3.11
July	3,920	826	1,990	122,000	1.16	1.34
August	791	507	613	37,700	.36	.42
September	507	450	564	33,600	.33	.37
October	756	435	492	30,300	.29	.33
November	1,370	603	749	44,600	.44	.49
December	603	450	549	33,800	.32	.37
The year	11,200	400	1,510	1,090,000	.88	12.00

NOTE.—Values are good.

CHELAN RIVER DRAINAGE BASIN.

Chelan River forms the outlet of Lake Chelan, a long, narrow lake fed at the upper end by Stehekin River, which drains a portion of the eastern slopes of the Cascades. The tributaries of this lake drain a rough, mountainous area, quite heavily timbered. The lower end of the lake is 380 feet above Columbia River, to which it is joined by Chelan River, about 4 miles in length. The water supply of this stream is particularly valuable for future power development.

CHELAN RIVER AT CHELAN, WASH.

This station was established November 6, 1903, by G. H. Bliss. It is located at the highway bridge 3,000 feet below the outlet of the lake and in the town of Chelan. A dam which has been constructed at the foot of the lake by the town of Chelan holds back the flow of water to some extent during the dry season. The conditions at the station and the bench marks are described in Water-Supply Paper

No. 178, page 38, where are given also references to publications that contain data for previous years.

The following measurement was made January 2, 1907:

Width, 206 feet; area, 1,460 feet; gage height, 5.50 feet; discharge, 920 second-feet.

Daily gage height, in feet, of Chelan River at Chelan, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5.40	5.70	5.60	5.85	7.75	8.45	7.65	7.20	6.20	5.75	5.55	7.15
2	5.40	5.68	5.60	5.90	7.90	8.45	7.70	7.15	6.15	5.70	5.50	7.10
3	5.40	5.65	5.60	5.90	8.05	8.50	7.80	7.15	6.10	5.70	5.45	7.05
4	5.40	5.65	5.60	5.90	8.20	8.45	8.00	7.05	6.10	5.65	5.40	7.00
5	5.40	5.65	5.60	5.95	8.30	8.40	8.15	7.00	6.00	5.60	5.40	7.00
6	5.38	5.65	5.55	6.02	8.35	8.40	8.25	6.50	5.95	5.60	5.40	7.00
7	5.38	5.65	5.55	6.40	8.30	8.35	8.40	6.50	5.90	5.55	5.40	6.95
8	5.40	5.65	6.65	6.40	8.30	8.35	8.50	6.50	5.90	5.50	5.40	6.95
9	5.40	5.65	6.58	6.50	8.32	8.35	8.50	6.50	5.90	5.55	5.50	6.90
10	5.40	5.65	6.50	6.48	8.40	8.30	8.45	6.50	5.85	5.55	5.50	6.90
11	5.40	5.60	6.43	6.52	8.50	8.30	8.40	6.50	5.90	5.60	5.55	6.85
12	5.45	5.60	6.38	6.50	8.65	8.35	8.40	6.50	6.00	5.60	5.65	6.80
13	5.48	5.60	6.30	6.50	8.70	8.35	8.38	6.45	6.25	5.60	5.80	6.70
14	5.48	5.60	6.25	6.50	8.70	8.30	8.35	6.45	6.15	5.60	6.10	6.60
15	5.45	5.65	6.22	6.55	8.70	8.30	8.35	6.40	6.10	5.60	6.50	6.55
16	5.50	5.65	6.20	6.60	8.65	8.25	8.35	6.40	6.00	5.60	7.00	6.50
17	5.45	5.65	6.18	6.65	8.60	8.20	8.33	6.35	5.95	5.60	7.50	6.40
18	5.45	5.65	6.10	6.60	8.55	8.15	8.30	6.35	5.95	5.57	7.70	6.40
19	5.40	5.65	6.00	6.70	8.50	8.10	8.20	6.30	5.95	5.55	7.60	6.35
20	5.40	5.65	5.92	6.75	8.40	7.95	8.10	6.28	5.95	5.50	7.50	6.35
21	5.40	5.60	5.88	6.92	8.30	7.75	8.00	6.25	5.90	5.45	7.45	6.30
22	5.40	5.65	5.85	7.00	8.25	7.65	7.90	6.20	5.90	5.40	7.40	6.30
23	5.90	5.65	5.82	7.15	8.20	7.50	7.80	6.15	5.90	5.40	7.40	6.30
24	5.85	5.70	5.80	7.25	8.15	7.40	7.70	6.08	5.85	5.38	7.40	6.20
25	5.85	5.65	5.80	7.35	8.20	7.50	7.60	6.00	5.90	5.80	7.35	6.10
26	5.80	5.70	5.78	7.40	8.35	7.60	7.60	6.00	5.85	5.85	7.35	6.00
27	5.80	5.70	5.78	7.42	8.45	7.70	7.55	6.05	5.85	5.90	7.30	5.90
28	5.75	5.65	5.75	7.45	8.50	7.70	7.50	6.05	5.80	5.80	7.25	5.90
29	5.75	....	5.72	7.50	8.50	7.68	7.50	6.10	5.78	5.65	7.20	5.85
30	5.70	....	5.72	7.60	8.50	7.65	7.40	6.20	5.75	5.65	7.20	5.80
31	5.70	....	5.82	....	8.50	....	7.30	6.20	....	5.60	....	5.70

Rating table for Chelan River at Chelan, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
5.30	830	6.00	1,150	6.70	1,920	7.30	2,910	7.90	3,990
5.40	860	6.10	1,230	6.80	2,070	7.40	3,090	8.00	4,170
5.50	900	6.20	1,320	6.90	2,230	7.50	3,270	8.20	4,550
5.60	940	6.30	1.420	7.00	2,390	7.60	3.450	8.40	4,930
5.70	990	6.40	1,530	7.10	2,560	7.70	3,630	8.60	5,300
5.80	1,040	6.50	1,650	7.20	2,730	7.80	3,810	8.80	5,690
5.90	1,090	6.60	1,780						

Note.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903-1907, and is fairly well defined above gage height 5.5 feet.

Monthly discharge of Chelan River at Chelan, Wash., for 1906.

[Drainage area, 950 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	1,090	854	916	56,300	.964	1.11
February	990	940	965	53.600	1.02	1.06
March	1,850	920	1,170	71,900	1.23	1.42
April	3,450	1,050	1,990	118,000	2.09	2.33
May	5,500	3.720	4,890	301,000	5.15	5.94
June	5,110	3,090	4,330	258.000	4.56	5.09
July	5.110	2,910	4,210	259,000	4.43	5.11
August	2,730	1,150	1,620	99,600	1.71	1.97
September	1,370	992	1,130	67,200	1.19	1.33
October	1,080	812	921	56,600	.969	1.12
November	3,630	820	1,990	118,000	2.09	2.33
December	2,640	965	1,750	108.000	1.84	2.12
The year	5,500	812	2,100	1,570,000	2.27	30.93

NOTE.—Values are good.

WENATCHEE RIVER DRAINAGE BASIN.

WENATCHEE RIVER AT CASHMERE, WASH.

Wenatchee River drains a portion of the western slope of the Cascade Mountains in Washington, and flows southeast through Lake Wenatchee into the Columbia River. Its basin throughout is mountainous and quite heavily timbered. The rainfall varies from 50 inches at the crest of the Cascades to 20 inches at the mouth. The waters of the stream are principally valuable for irrigation.

This station was established July 26, 1904. It is located at the highway bridge just north of the town of Cashmere, Wash. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 40, where are given also references to publications that contain data for previous years.

The old gage was destroyed by flood November 15, 1906. A new gage was installed at the same place and datum on December 27.

Discharge measurements of Wenatchee River at Cashmere, Wash., in 1906.

Date.	Hydrographer	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
August 23	W. G. Steward	160	232	1.55	889
August 29	do	161	737	1.55	956
December 27	H. McGlashan	186	312	2.20	1,300

Daily gage height, in feet, of Wenatchee River at Cashmere, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.3	2.4	2.0	3.6	6.0	4.6	3.6	2.2	1.8	1.5	3.2	......
2	1.3	2.5	2.0	3.5	6.1	4.6	3.8	2.1	1.8	1.4	2.9	......
3	1.4	2.6	2.0	3.3	6.3	4.9	4.1	2.0	1.7	1.5	2.8	......
4	1.5	2.5	1.9	3.4	6.1	5.5	4.4	1.9	1.7	1.7	2.8	......
5	1.7	2.5	1.9	3.6	5.9	5.3	4.5	2.0	1.6	1.7	2.9	......
6	1.7	2.4	2.0	4.0	5.5	4.9	4.5	2.0	1.4	1.7	2.6	......
7	1.6	2.4	2.0	4.4	5.3	4.6	4.7	2.0	1.4	1.7	2.6	......
8	1.6	2.3	2.1	5.0	5.3	4.4	4.4	2.0	1.9	1.6	2.7	......
9	1.5	2.2	2.2	4.6	5.4	4.2	4.1	2.0	2.4	1.5	2.7	......
10	1.5	2.1	2.3	4.3	5.9	4.1	3.9	2.0	2.3	1.6	2.7	......
11	1.5	2.1	2.3	4.2	6.2	4.0	3.7	2.0	2.0	1.5	3.4	......
12	1.4	2.1	2.2	4.1	6.0	4.9	3.6	2.0	1.7	1.5	3.4	......
13	1.4	2.0	2.1	4.0	5.8	5.0	3.6	2.0	1.6	1.7	5.7	......
14	1.3	2.0	2.1	3.8	5.3	4.6	3.5	2.1	1.6	1.8	8.05	......
15	1.4	2.0	2.0	3.9	5.3	4.3	3.4	2.0	1.6	2.0	......	......
16	1.4	1.9	2.0	4.2	4.9	4.3	3.3	1.9	1.6	2.4	......	......
17	1.4	1.9	2.0	4.4	4.6	4.2	3.2	1.85	1.5	2.7	......	......
18	1.4	2.0	2.0	4.3	4.4	4.0	3.1	1.8	1.5	3.0	......	......
19	1.3	2.3	2.0	4.3	4.3	3.9	3.0	1.6	1.4	2.8	......	......
20	1.3	2.5	2.0	4.4	4.2	3.8	2.9	1.6	1.4	2.7	......	......
21	1.3	2.4	2.0	4.8	4.2	3.8	2.8	1.6	1.4	2.3	......	......
22	1.4	2.3	2.0	5.85	4.1	3.8	2.7	1.6	1.4	2.2	......	......
23	1.5	2.3	2.0	5.8	4.2	3.8	2.7	1.6	1.4	2.1	......	......
24	1.8	2.2	2.0	5.6	4.2	3.9	2.6	1.5	1.4	2.0	......	......
25	2.3	2.2	2.1	5.3	4.3	4.1	2.5	1.5	1.5	1.8	......	......
26	2.4	2.1	2.2	5.0	5.4	4.4	2.5	1.6	1.8	6.5	......	......
27	2.4	2.1	2.3	4.9	5.5	4.3	2.4	1.7	1.8	6.0	......	2.2
28	2.3	2.1	2.4	4.9	5.2	4.2	2.3	1.7	1.6	5.0	......	2.2
29	2.3	......	2.5	5.3	4.9	3.9	2.3	1.8	1.5	4.3	......	2.1
30	2.2	......	2.7	5.6	4.8	3.7	2.3	1.8	1.4	3.8	......	2.1
31	2.3	......	3.4	......	4.7	......	2.3	1.8	......	3.5	......	2.1

Rating table for Wenatchee River at Cashmere, Wash., for 1905–6.

gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.00	550	2.00	1,360	3.00	2,450	4.00	3,800	6.00	6,900
1.10	615	2.10	1,460	3.10	2,580	4.20	4,100	6.20	7,240
1.20	685	2.20	1,560	3.20	2,710	4.40	4,400	6.40	7,580
1.30	755	2.30	1,665	3.30	2,840	4.60	4,700	6.60	7,920
1.40	830	2.40	1,770	3.40	2,970	4.80	5,000	6.80	8,260
1.50	910	2.50	1,875	3.50	3,100	5.00	5,300	7.00	8,600
1.60	990	2.60	1,985	3.60	3,240	5.20	5,620	8.00	10,400
1.70	1,075	2.70	2,095	3.70	3,380	5.40	5,940		
1.80	1,165	2.80	2,210	3.80	3,520	5.60	6,260		
1.90	1,260	2.90	2,330	3.90	3,660	5.80	6,580		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904-1906 and is well defined between gage heights 1.5 feet and 3.9 feet.

Monthly discharge of Wenatchee River at Cashmere, Wash., for 1906.

[Drainage area, 1,190 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	1,770	755	1,060	65,200	0.891	1.03
February	1,980	1,260	1,910	106,000	1.61	1.68
March	2,970	1,260	1,520	93,500	1.28	1.48
April	6,660	2,840	4,540	270,000	3.82	4.26
May	7,410	3,950	5,600	344,000	4.71	5.43
June	6,100	3,380	4,310	256,000	3.62	4.04
July	4,850	1,660	2,920	180,000	2.45	2.82
August	1,560	910	1,220	75,000	1.03	1.19
September	1,770	830	1,030	61,300	.866	.97
October	7,750	830	2,060	127,000	1.73	1.99
November 1-14	10,500	1,980	3,210	89,100	2.70	1.41
December 27–31	1,560	1,460	1,500	14,900	1.26	.23
The period	....	....	....	1,680,000	....	....

NOTE.—Values are rated as follows: January to March and July to November, excellent; April to June, good.

YAKIMA RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Yakima River rises in Lake Keechelus, near the crest of the eastern slope of the Cascade Mountains, in Washington, and flows southeast into the Columbia River at Kennewick. The headwaters of this stream are fed by numerous tributaries draining rough mountainous areas of heavy timber lands. It is fed near its source by Kachess River, which heads in Lake Kachess, and by Clealum River, which flows through Lake Clealum. Throughout the arid portion of this drainage area the country is timberless and rolling except in the immediate valleys of the streams. The annual rainfall varies from 100 inches at the crest of the Cascades to 10 inches near the mouth of the river. The entire summer flow of the Yakima and also that of its principal tributary, Naches River, is diverted for the irrigation of lands which have reached a high stage of development, rivaled only by the orange lands of southern California.

Gaging stations are maintained as follows:

Yakima River near Martin, Clealum, Umtanum, Yakima, Prosser, Kiona, and Richland, Wash.; Kachess River near Easton, Wash.; Clealum River near Roslyn; Nachez River near Nile and North Yakima; Bumping River near Nile; and Tieton River near Natchez (two stations). Gages for determining fluctuations of water level are maintained in Lakes Keechelus, Kachess, and Clealum.

YAKIMA RIVER NEAR MARTIN, WASH.

This station was established October 18, 1903. It is 1,000 feet below the outlet of Lake Keechelus, 800 feet below the dam of the Cascade Lumber Company, and 4 miles northwest of Martin, Wash. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 43, where are given also references to publications that contain data for previous years.

Discharge measurements of Yakima River near Martin, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 18	J. C. Stevens	113	191	7.04	194
May 2	W. C. Muldrow	120	394	8.74	983
July 17	do	108	186	6.90	169
August 11	do	105	133	6.43	68
August 21 [a]	J. C. Stevens	48	45	6.37	66
October 30	W. C. Muldrow	119	295	8.01	582
November 25	do	109	208	7.18	246

[a] Made 500 feet below cable.

Daily gage height, in feet, of Yakima River near Martin, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.86	7.40	7.26	7.45	8.79	7.91	7.39	6.52	6.32	6.52	7.56	6.55
2	6.82	7.32	7.22	7.50	8.75	7.90	7.39	6.52	6.31	6.54	7.29	6.52
3	6.80	7.27	7.15	7,48	8.72	7.91	7.39	6.50	6.31	6.62	7.24	6.52
4	6.82	7.21	7.10	7.48	8.70	8.01	7.36	6.50	6.30	6.79	7.21	......
5	6.86	7.17	7.07	7.56	8.59	7.98	7.34	6.48	6.30	6.82	7.14	......
6	6.92	7.14	7.04	7.71	8.44	7.94	7.32	6.47	6.28	6.80	6.94	......
7	6.90	7.13	7.03	7.90	8.36	7.90	7.26	6.47	6.34	6.76	7.10	......
8	6.90	7.12	7.04	8.01	8.31	7.82	7.22	6.46	6.34	6.72	7.22	6.80
9	6.92	7.10	7.10	8.05	8.38	7.76	7.16	6.45	6.36	6.69	7.31	6.90
10	6.91	7.10	7.12	8.01	8.52	7.71	7.13	6.44	6.36	6.74	7.70	6.91
11	6.90	7.08	7.15	7.92	8.58	7.70	7.11	6.43	6.34	6.71	8.04	7.67
12	6.88	7.06	7.16	7.82	8.54	7.79	7.05	6.43	6.33	6.74	8.50	8.20
13	6.88	7.04	7.14	7.73	8.40	7.74	7.02	6.42	6.32	6.72	11.28	7.91
14	6.85	7.04	7.12	7.66	8.26	7.71	6.99	6.42	6.50	6.66	13.80	7.40
15	6.84	7.02	7.08	7.66	8.28	7.66	6.94	6.40	6.52	6.79	13.96	7.62
16	6.88	7.02	7.06	7.62	8.18	7.62	6.92	6.40	6.50	7.04	11.74	7.40
17	6.88	7.04	7.06	7.78	8.13	7.59	6.89	6.40	6.48	7.61	10.04	7.75
18	7.00	7.08	7.04	7.84	8.02	7.56	6.85	6.39	6.46	7.81	9.14	7.63
19	7.10	7.37	7.04	7.86	7.93	7.54	6.81	6.38	6.45	7.80	8.42	7.02
20	7.20	7.50	7.01	7.92	7.88	7.52	6.78	6.38	6.44	7.71	8.06	7.72
21	7.42	7.53	6.98	8.34	7.82	7.51	6.76	6.37	6.42	7.58	7.71	8.25
22	7.58	7.52	6.96	8.64	7.80	7.57	6.74	6.36	6.42	7.46	7.39	8.15
23	7.75	7.50	6.96	8.73	7.74	7.54	6.72	6.35	6.41	7.44	7.21	7.99
24	7.82	7.50	6.94	8.62	7.73	7.52	6.67	6.34	6.42	7.42	6.92	7.93
25	7.85	7.46	6.92	8.56	7.82	7.50	6.64	6.34	6.48	7.52	7.18	7.85
26	7.82	7.39	6.94	8.48	8.06	7.46	6.62	6.33	6.51	7.62	7.11	......
27	7.79	7.35	6.98	8.41	8.09	7.44	6.60	6.33	6.52	7.82	7.08	......
28	7.71	7.30	7.01	8.39	8.02	7.42	6.58	6.33	6.54	7.91	6.79	......
29	7.63	....	7.04	8.44	7.94	7.42	6.56	6.32	6.52	8.01	....	......
30	7.55	....	7.11	8.60	8.00	7.40	6.55	6.32	6.52	7.78	6.56	......
31	7.46	....	7.28	....	7.97	....	6.54	6.32	....	7.62	....	8.40

NOTE.—Water was entirely shut off at the lake November 29, December 4 to 7, and December 26 to 30, and for partial days at other times in December. Gage heights November 12 to 17 were computed by plotting several readings a day and taking the mean from the curve.

Rating table for Yakima River near Martin, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
6.20	42	7.00	180	7.80	470	8.60	890	9.80	1,730
6.30	54	7.10	207	7.90	515	8.70	950	10.00	1,900
6.40	66	7.20	237	8.00	560	8.80	1,010	11.00	2,800
6.50	80	7.30	270	8.10	610	8.90	1,075	12.00	3,850
6.60	96	7.40	306	8.20	660	9.00	1,140	13.00	5,000
6.70	114	7.50	345	8.30	715	9.20	1,275	14.00	6,200
6.80	134	7.60	385	8.40	770	9.40	1,415		
6.90	156	7.70	425	8.50	830	9.60	1,570		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904-1906, and is well defined between gage heights 6.2 feet and 9.0 feet.

Monthly discharge of Yakima River near Martin, Wash., for 1906.

[Drainage area, 56 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	492	134	250	15,400	4.46	5.14
February	357	185	255	14,200	4.55	4.74
March	263	161	200	12,300	3.57	4.12
April	968	326	581	34,600	10.38	11.58
May	1,000	438	682	41,900	12.18	14.04
June	565	306	416	24,800	7.43	8.29
July	302	86	177	10,900	3.16	3.64
August	83	56	67.3	4,140	1.20	1.38
September	86	52	68.9	4,100	1.23	1.37
October	565	83	265	16,300	4.73	5.45
November	6,150	0	979	58,300	17.48	19.51
December	770	0	272	16,700	4.86	5.60
The year	6,150	0	351	254,000	6.27	84.86

NOTE.—Values are rated as follows: January to October, excellent; November and December, fair.

YAKIMA RIVER AT CLEALUM, WASH.

This station was established August 25, 1906. It is located at the highway bridge just above the town of Clealum. It is below the principal tributaries which drain the upper portion of its basin, and shows the water supply available for the Kittitas Valley.

The channel is straight for about 300 feet above and below the station. The current is swift. The right bank is low and liable to overflow; the left is high and rocky; both banks are wooded. The bed of the stream is of cobblestones and gravel and not likely to change except during high floods. There is one channel at all stages.

Measurements are made from the bridge. The initial point for soundings is the center of the downstream pier on the right bank.

A chain gage is fastened to the bridge and is read by T. J. Denny. The bench mark is a spike in a 30-inch cottonwood tree, 30 feet downstream from the right-bank pier; elevation, 8.80 feet above the datum of the gage.

Discharge measurements of Yakima River at Clealum, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
August 24	J. C. Stevens	190	225	2.27	483
September 25	W. C. Muldrow	190	226	2.20	470
October 31	do	209	546	3.92	2,230

Daily gage height, in feet, of Yakima River at Clealum, Wash., for 1906.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	2.30	2.28	3.62	6.80	17	....	2.30	2.80	....	3.78
2	....	2.30	2.25	3.48	6.70	18	....	2.28	3.05	....	3.80
3	....	2.30	2.25	3.38	6.62	19	....	2.25	3.20	....	3.80
4	....	2.28	2.32	3.28	6.50	20	....	2.25	3.20	....	4.10
3	....	2.25	2.40	3.02	6.50	21	....	2.22	3.12	....	4.60
6	....	2.25	2.40	2.88	6.50	22	....	2.20	3.00	....	4.90
7	....	2.25	2.40	2.95	6.50	23	....	2.20	3.00	....	4.80
8	....	2.25	2.40	3.10	6.55	24	2.25	2.20	3.00	....	4.70
9	....	2.28	2.40	3.08	5.28	25	2.30	2.25	2.95	....	4.60
10	....	2.28	2.40	3.30	4.05	26	2.30	2.30	5.50	....	4.25
11	....	2.25	2.40	3.85	4.00	27	2.30	2.30	6.00	....	4.05
12	....	2.25	2.40	4.22	4.20	28	2.30	2.30	5.25	7.15	4.00
13	....	2.25	2.40	6.68	4.35	29	2.30	2.30	4.60	7.00	3.95
14	....	2.30	2.40	....	4.20	30	2.30	2.30	4.15	6.82	3.90
15	....	2.30	2.45	....	3.95	31	2.30	....	3.80	....	2.75
16	....	2.30	2.55	....	4.05						

Rating table for Yakima River at Clealum, Wash., from August 24 to October 25, 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.00	330	2.30	505	2.60	730	2.90	1,000	3.20	1,310
2.10	380	2.40	575	2.70	815	3.00	1,100		
2.20	440	2.50	650	2.80	905	3.10	1,200		

NOTE.—The above table is based on 3 discharge measurements made during 1906 and is not well defined.

Monthly discharge of Yakima River at Clealum, Wash., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
August 24-31	505	472	501	7,950
September	505	440	484	28,800
October 1-25	1,310	472	770	38,200
The period				75,000

NOTE.—Values are good.

YAKIMA RIVER AT UMTANUM, WASH.

This station was established August 25, 1906. It is located in a canyon about 100 yards from the railroad tracks and opposite the station at Umtanum, about 6 miles above Roza, on the Northern Pacific Railroad. The station is below Kittitas Valley and above Selah and Yakima valleys.

The channel is straight for about 200 feet above and below the station. There is a riffle control about 300 feet below. The right bank is low and liable to overflow to the railroad embankment; the left is high and rocky. The right half of the bed of the stream is composed of gravel and cobblestones; the left is of solid rock. There is one channel at all stages.

Discharge measurements are made from a cable and car. There is a stay line 75 feet upstream from the cable. The initial point for soundings is the face of a small cottonwood tree 10 inches in diameter, 15 feet upstream from the gage, on the right bank, about 25 feet from the water's edge.

The gage, which was read during the season by B. F. Cummings, is a 2 by 4 inch timber fastened in a vertical position on the right bank, back of the section house. The bench mark is a mark on a bowlder 100 feet west of the section house and 40 feet north of the Northern Pacific track, opposite the gage; elevation, 16.30 feet above the datum of the gage.

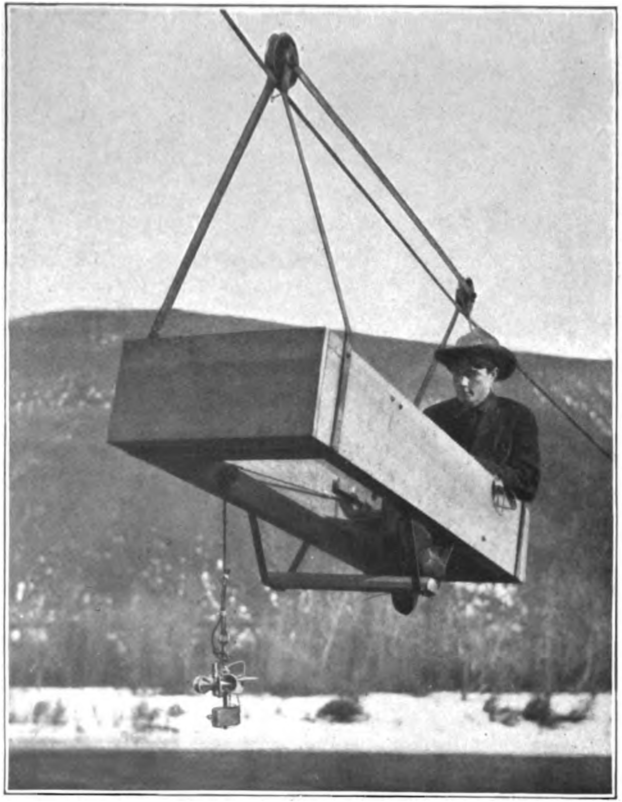
The following measurement was made August 25, 1906:

Width, 230 feet; area, 414 feet; gage height, 3.07 feet; discharge, 365 second-feet.

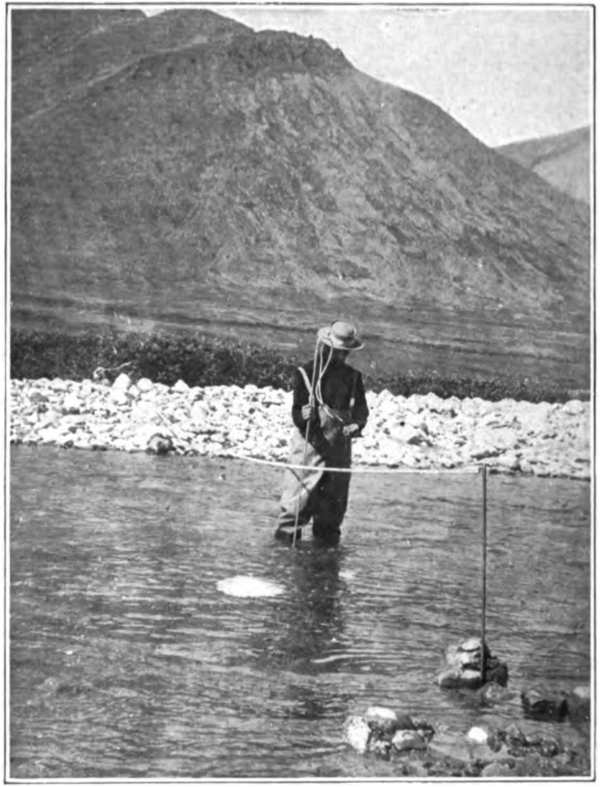
Daily gage height, in feet, of Yakima River at Umtanum, Wash., for 1906.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1		2.98	3.20	4.55	5.88	17		3.08	3.55		4.56
2		2.98	3.22	4.46	5.72	18		3.08	3.70		4.61
3		3.00	3.25	4.34	5.50	19		3.10	4.00		4.66
4		3.00	3.28	4.30	5.18	20		3.10	4.10		4.80
5		2.99	3.31	4.12	5.05	21		3.06	4.08		5.00
6		2.98	3.38	4.08	4.88	22		3.06	4.05		5.06
7		2.98	3.48	4.00	4.68	23		3.06	4.00		5.04
8		2.98	3.45	4.08	4.52	24		3.10	3.96		5.11
9		2.98	3.45	4.15	4.56	25	3.07	3.12	3.88		5.16
10		2.97	3.42	4.32	4.70	26	3.00	3.16	4.88		5.13
11		2.98	3.40	4.45	4.70	27	3.00	3.20	6.40		5.00
12		3.04	3.40	5.18	4.71	28	3.03	3.24	6.00	6.20	4.92
13		3.06	3.40	6.78	4.69	29	3.00	3.22	5.30	6.01	4.82
14		3.10	3.42	9.66	4.65	30	3.00	3.20	4.95	5.94	4.60
15		3.10	3.45		4.62	31	2.95		4.75		4.34
16		3.07	3.45	14.2	4.59						

NOTE.—The upper portion of the gage was washed away November 15, so that no readings could be obtained until the 28th. The gage height of November 16 is the maximum.



A. CABLE STATION, YAKIMA RIVER, NEAR UNION GAP, WASHINGTON.



B. DISCHARGE MEASUREMENT BY WADING.

YAKIMA RIVER NEAR YAKIMA, WASH.

The station was originally established August 14, 1893, at the county bridge at Union Gap (Pl. III, *A*), 2 miles below Yakima, Wash. In August, 1895, a cable and new gage were installed about 1,000 feet below the bridge, and about 3 miles above the intake of the Sunnyside Canal. The station is of value, as it is the only point near the large irrigated areas above and below which is unaffected by the diversion of water. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 46, where are given also references to publications that contain data for previous years.

Discharge measurements of Yakima River near Yakima, Wash., in 1905–1907.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1905.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 19	W. J. Lightfoot	236	1,340	6.10	3,920
September 2	W. C. Muldrow	230	753	3.64	780
October 26	do	240	1,250	5.60	3,570
November 18	Sawyer and Muldrow	238	960	4.32	1,600
1906.					
March 26	J. C. Stevens	240	1,190	5.29	2,900
April 30	W. C. Muldrow	340	1,800	7.62	9,790
July 9	do	241	1,100	5.14	2,840
August 3	do	232	687	3.52	748
September 29	Stevens and Grover	234	723	3.60	790
October 27	Muldrow and McGlashan	249	1,620	7.29	6,770
December 29	W. C. Muldrow	242	1,810	5.68	4,040
1907.					
February 20	W. C. Muldrow	300	2,190	7.03	7,740
February 22	do	300	2,410	7.69	9,770

Daily gage height, in feet, of Yakima River near Yakima, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.1	5.85	5.9	7.6	8.0	6.2	5.7	3.6	3.4	3.55	5.4	5.7
2	4.1	5.9	5.8	7.4	8.1	6.2	5.0	3.5	3.4	3.5	5.25	5.6
3	4.1	5.9	5.6	7.2	8.2	6.6	5.1	3.5	3.35	3.6	5.15	5.5
4	4.05	6.0	5.4	7.1	8.1	6.8	5.0	3.5	3.35	3.65	5.0	5.3
5	4.1	6.0	5.3	7.3	8.0	6.9	5.1	3.4	3.35	3.8	4.8	5.2
6	4.15	5.9	5.2	7.9	8.0	6.6	5.2	3.4	3.35	3.9	5.0	5.15
7	4.2	5.8	5.2	8.1	7.9	6.3	5.3	3.45	3.4	3.9	5.3	5.15
8	4.2	5.6	5.6	8.2	7.6	6.1	5.2	3.45	3.4	3.9	5.3	5.6
9	4.2	5.5	5.8	8.2	7.4	6.0	5.1	3.45	3.4	3.9	5.4	5.5
10	4.2	5.45	5.8	7.9	7.4	6.0	5.0	3.45	3.45	3.85	5.4	5.5
11	4.2	5.3	5.7	7.7	7.8	5.9	5.0	3.45	3.4	3.9	6.2	5.55
12	4.2	5.3	5.7	7.4	7.6	5.9	4.9	3.55	3.4	3.9	6.9	5.4
13	4.2	5.1	5.6	7.3	7.6	6.0	4.8	3.45	3.4	3.9	10.84	5.3
14	4.1	5.0	5.5	7.1	7.4	6.1	4.9	3.5	3.5	3.9	13.36	5.3
15	4.1	5.0	5.5	7.0	7.0	6.0	4.9	3.55	3.55	3.9	15.68	5.2
16	4.1	5.0	5.4	7.2	6.9	6.0	4.6	3.5	3.55	4.0	14.18	5.2
17	4.1	5.05	5.4	7.4	6.6	5.9	4.5	3.5	3.55	4.3	11.94	5.1
18	4.1	5.2	5.3	7.3	6.4	5.9	4.5	3.45	3.5	4.5	10.2	5.0
19	4.0	5.8	5.2	7.3	6.2	5.8	4.5	3.45	3.5	4.6	8.9	5.0
20	4.05	6.0	5.2	7.4	6.1	5.8	4.4	3.45	3.5	4.6	8.6	6.3
21	4.1	6.0	5.15	7.7	6.0	5.7	4.4	3.45	3.5	4.6	8.0	6.5
22	4.3	6.1	5.1	7.9	6.0	5.6	4.2	3.4	3.5	4.55	7.4	6.5
23	4.4	6.2	5.1	8.3	5.9	5.4	4.1	3.35	3.55	4.5	7.1	6.7
24	4.7	6.2	5.1	8.6	5.9	5.4	4.0	3.4	3.55	4.5	6.9	6.6
25	5.1	6.2	5.1	8.1	5.9	5.5	4.0	3.4	3.5	4.55	6.7	6.5
26	5.3	6.1	5.2	7.9	6.3	5.5	3.9	3.4	3.5	4.6	6.3	6.4
27	5.3	6.0	5.6	7.5	7.0	5.5	3.9	3.35	3.55	7.3	6.1	6.3
28	5.5	6.0	5.8	7.5	6.9	5.4	3.8	3.35	3.55	7.3	6.0	6.0
29	5.5	......	6.0	7.6	6.8	5.3	3.8	3.4	3.55	6.9	5.9	5.9
30	5.55	......	6.3	7.8	6.7	5.3	3.7	3.4	3.5	6.5	5.9	5.7
31	5.9	......	6.4	......	6.6	......	3.7	3.4	......	6.0	......	5.6

NOTE.—Gage heights November 12 to 17 were found by plotting several readings a day and taking the mean from the curve.

Rating tables for Yakima River near Yakima, Wash.

JANUARY 1, 1904, TO JUNE 4, 1905.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
3.80	920	4.70	1,800	5.60	3,070	6.50	5,035	7.80	9,170
3.90	1,000	4.80	1,920	5.70	3,240	6.60	5,295	8.00	9,930
4.00	1,090	4.90	2,045	5.80	3,420	6.70	5,565	8.20	10,740
4.10	1,180	5.00	2,180	5.90	3,615	6.80	5,835	8.40	11,600
4.20	1,280	5.10	2,315	6.00	3,830	6.90	6,115	8.60	12,480
4.30	1,380	5.20	2,455	6.10	4,055	7.00	6,405	8.80	13,360
4.40	1,480	5.30	2,600	6.20	4,285	7.20	7,025	9.00	14,240
4.50	1,580	5.40	2,750	6.30	4,525	7.40	7,720	9.20	15,120
4.60	1,690	5.50	2,910	6.40	4,775	7.60	8,440		

JUNE 5, 1905, TO DECEMBER 31, 1906.[b]

3.00	460	4.10	1,290	5.20	2,840	6.60	6,220	8.80	14,670
3.10	500	4.20	1,405	5.30	3,020	6.80	6,890	9.00	15,600
3.20	550	4.30	1,520	5.40	3,210	7.00	7,590	10.00	20,800
3.30	605	4.40	1,640	5.50	3,400	7.20	8,290	11.00	26,700
3.40	665	4.50	1,760	5.60	3,600	7.40	9,010	12.00	33,200
3.50	725	4.60	1,890	5.70	3,810	7.60	9,750	13.00	40,500
3.60	795	4.70	2,030	5.80	4,030	7.80	10,510	14.00	48,600
3.70	875	4.80	2,180	5.90	4,260	8.00	11,300	15.00	57,400
3.80	965	4.90	2,340	6.00	4,500	8.20	12,100	16.00	67,000
3.90	1,070	5.00	2,500	6.20	5,030	8.40	12,930		
4.00	1,180	5.10	2,670	6.40	5,600	8.60	13,780		

[a] This table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904-5 and is well defined.

[b] This table is applicable only for open-channel conditions. It is based on 12 discharge measurements made during 1905-6 and is well defined between gage heights 3.5 feet and 7.7 feet. The extension of the table is based on a discharge for the maximum gage height of 1906 computed from a measurement at Kiona.

Monthly discharge of Yakima River near Yakima, Wash., for 1905-6.

[Drainage area, 3,300 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.						
January	2,180	1,280	1,830	113,000	0.554	0.64
February	3,620	920	1,730	95,900	.523	.54
March	9,550	3,830	7,540	463,000	2.28	2.63
April	9,930	3,420	4,750	283,000	1.44	1.61
May	7,720	3,830	4,930	303,000	1.49	1.72
June	14,700	5,310	8,320	495,000	2,52	2.81
July	5,900	1,290	2,710	167,000	.821	.95
August	1,290	795	922	56,700	.279	.32
September	1,180	795	904	53,800	.274	.31
October	5,750	1,290	3,200	197,000	.970	1.12
November	2,670	1,520	1,880	112.000	.570	.64
December	2,100	1,400	1,700	105,000	.515	.59
The year	14,700	795	3,370	2,440,000	1.02	13.88
1906.						
January	4,260	1,180	1,820	112,000	0.552	0.64
February	5,030	2,500	3,880	215,000	1.18	1.23
March	5,600	2,670	3,480	214.000	1.05	1.21
April	13,800	7,590	9,900	589,000	3.00	3.35
May	12,100	4,260	7,910	486.000	2.40	2.77
June	7,240	3.020	4,410	262,000	1.34	1.50
July	3,810	965	1,970	121,000	.600	.69
August	795	635	694	42,700	.210	.24
September	760	635	705	42,000	.212	.24
October	8,650	725	2,220	136,000	.673	.78
November	63.900	2,180	12,400	738,000	3.76	4.20
December	6,550	2,500	3,920	241,000	1.19	1.37
The year	63.900	635	4,440	3,200,000	1.35	18.20

NOTE.—Values are rated as follows: 1905 and January to June, 1906, excellent; July to December, 1906, fair.

YAKIMA RIVER AT PROSSER, WASH.

This station was established February 8, 1906, to replace the old station at the highway bridge below Prosser Falls, described in Water-Supply Paper No. 178, page 48. It was abandoned October 12, 1906, as it was found unsuited for low-water measurements and as the flow was controlled by dams above. It was located 1½ miles below the town of Prosser, about 1¼ miles below the county bridge across Yakima River and the power plant of the Prosser Falls Land and Power Company, and about 2,000 feet from the Northern Pacific Railroad tracks.

The channel is straight, and the current fairly swift except at low stages. The banks are of earth, intermingled with basaltic bowlders; the right bank is high; the left is low and liable to overflow at extreme high water. The bed of the stream is composed of massive bowlders and angular cobblestones. There is one channel at all stages.

Discharge measurements were made from a cable and car, which was removed when the station was abandoned. The initial point for soundings is a cross on a large bowlder, 2 feet back of the shear legs on the left bank.

A wooden inclined gage, which was read by G. W. Booth, was located on the right bank, 80 feet upstream from the shear legs. The bench mark is the top of a copper plug in a large bowlder about 40 feet downstream from the gage; elevation, 18.44 feet above the datum of the gage and 613.44 feet above sea level.

Discharge measurements of Yakima River at Prosser, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
February 8	W. C. Muldrow	310	1,720	7.20	4,160
February 23	do	312	1,990	8.04	5,450
March 24	J. C. Stevens	303	1,610	6.84	3,200
May 17	W. C. Muldrow	316	2,060	8.25	5,900
July 12	do	291	1,160	5.48	1,470
August 18	J. C. Stevens			3.00	[a] 100
November 17 [b]	D. C. Henny	662	7,470		62,800

[a] Estimated.

[b] Measured by floats from new highway bridge above the dam.

Daily gage height, in feet, of Yakima River at Prosser, Wash., for 1906.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	7.8	7.4	9.5	9.7	7.8	5.7	3.4	2.9	2.9
2	7.8	7.2	9.7	10.1	7.7	5.6	3.4	3.0	3.1
3	7.7	7.2	9.4	10.1	7.3	5.6	3.3	2.9	3.3
4	7.5	7.2	9.3	10.2	7.8	5.5	3.2	2.9	3.4
5	7.5	7.1	9.3	10.2	8.1	5.6	3.2	2.9	3.6
6	7.5	7.0	9.6	9.9	8.3	5.7	3.2	2.7	3.4
7	7.3	7.0	10.1	9.5	7.8	5.7	3.3	2.9	3.0
8	7.2	7.1	10.5	9.3	7.7	5.8	3.2	2.9	3.1
9	7.1	7.2	10.5	9.0	7.3	5.8	2.9	3.0	3.5
10	7.0	7.4	10.4	9.1	7.0	5.7	3.1	3.0	3.8
11	7.0	7.3	10.1	9.3	6.8	5.5	2.8	2.9	3.8
12	6.9	7.1	9.8	9.3	7.2	5.4	3.2	2.9	3.8
13	6.8	7.0	9.4	9.0	7.4	5.3	2.6	3.0	....
14	6.7	7.2	9.2	8.8	7.5	5.2	3.0	3.0	....
15	6.6	7.4	9.2	8.6	7.4	5.2	3.0	3.0	....
16	6.6	7.3	9.1	8.4	7.3	5.1	3.0	3.0	....
17	6.5	7.3	9.2	8.2	7.1	5.0	3.0	3.1	....
18	6.6	7.2	9.3	7.6	7.0	4.9	3.0	3.2	....
19	6.8	7.1	9.3	7.0	7.0	4.8	2.6	3.2	....
20	8.0	6.9	9.2	6.7	6.9	4.7	3.0	3.2	....
21	8.3	6.9	9.2	7.3	6.7	4.6	2.9	3.2	....
22	8.2	6.8	9.8	7.0	6.5	4.5	3.1	3.0	....
23	8.0	6.8	10.5	7.0	6.3	4.4	2.9	2.9	....
24	7.9	6.8	10.7	7.0	6.2	4.2	3.0	3.0	....
25	7.8	6.9	10.5	7.2	6.2	4.1	2.8	3.0	....
26	7.7	7.0	9.9	7.4	6.2	4.0	2.6	3.1	....
27	7.7	7.2	9.6	8.4	6.1	3.9	3.0	3.2	....
28	7.6	7.4	9.3	8.5	6.1	3.8	3.1	3.0	....
29	....	7.8	9.2	8.4	6.0	3.7	3.0	2.8	....
30	....	8.0	9.3	8.0	5.8	3.6	2.6	2.6	....
31	....	8.3	....	7.8	....	3.5	2.6	....	....

Rating table for Yakima River at Prosser, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.60	40	3.80	345	5.00	1,060	6.40	2,580	8.80	7,050
2.70	50	3.90	390	5.10	1,140	6.60	2,860	9.00	7,510
2.80	65	4.00	435	5.20	1,225	6.80	3,160	9.20	7,980
2.90	80	4.10	485	5.30	1,310	7.00	3,480	9.40	8,460
3.00	100	4.20	540	5.40	1,400	7.20	3,820	9.60	8,940
3.10	120	4.30	595	5.50	1,500	7.40	4,170	9.80	9,440
3.20	145	4.40	655	5.60	1,600	7.60	4,530	10.00	9,940
3.30	170	4.50	715	5.70	1,710	7.80	4,910	11.00	12,500
3.40	200	4.60	780	5.80	1,820	8.00	5,310		
3.50	230	4.70	845	5.90	1,940	8.20	5,730		
3.60	265	4.80	915	6.00	2,060	8.40	6,160		
3.70	305	4.90	985	6.20	2,310	8.60	6,600		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1906 and is well defined between gage heights 5 feet and 9 feet.

Monthly discharge of Yakima River at Prosser, Wash., for 1906.

[Drainage area, 5,050 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
February	5,940	2,720	4,150	230,000	0.822	0.86
March	5,940	3,160	3,860	237,000	.764	.88
April	11,700	7,740	9,130	543,000	1.81	2.02
May	10,400	3,010	6,580	405,000	1.30	1.50
June	5,940	1,820	3,600	214.000	.713	.80
July	1,820	230	1,080	66,400	.214	.25
August	200	40	106	6,520	.021	.02
September	145	40	98.0	5,830	.019	.02
October 1-12	345	80	210	5,000	.042	.02
The period				1,710,000		

NOTE.—Values are rated as follows: February to June, excellent; July, good; August to October, fair.

YAKIMA RIVER AT KIONA, WASH.

This station was established August 20, 1895. It is located at the highway bridge on the county road about 1,800 feet northwest of the Northern Pacific Railway station at Kiona, Wash. It is about 23 miles above the mouth of the river. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 49, where are given also references to publications that contain data for previous years.

The staff gage, installed December 23, 1905, was read from January 1 to March 22, 1906. Subsequent to that date the wire gage was used. These gages are referred to the following bench marks: (1) A standard U. S. Geological Survey iron bench-mark post near the Northern Pacific Railway station; elevation, 61.35 feet above the datum of the gage and 514.79 feet above mean sea level. (2) A standard U. S. Geological Survey iron bench mark in northeast corner of H. A. Shandy's lot near right approach of highway bridge; elevation, 18.99 feet above gage datum. These elevations were checked during 1906.

Discharge measurements of Yakima River at Kiona, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
February 21[a]	W. C. Muldrow	265	1,580	7.14	5,480
March 23	J. C. Stevens	275	1,200	5.72	2,870
May 8	W. C. Muldrow	301	1,850	8.09	7,700
July 11	do	217	925	4.64	1,560
July 30[b]	do	67	82	2.99	309
August 18[b]	Muldrow and Stevens	60	58	2.52	150
October 13[b]	W. C. Muldrow	75	96	3.07	285
November 17[c]	D. C. Henny	1,600	8,400	19.52	61,600
November 19[c]	W. C. Muldrow		4,250	15.00	31,700
December 18	do	265	1,310	6.14	3,570

[a] Mean of two measurements. [b] Measured by wading. [c] Measured by floats:

Daily gage height, in feet, of Yakima River at Kiona, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.55	6.35	6.35	8.5	8.7	6.8	4.8	2.8	2.45	2.75	5.8	6.55
2	4.55	6.45	6.25	8.8	9.2	6.7	4.8	2.8	2.4	2.8	5.7	6.55
3	4.55	6.65	6.15	8.6	9.4	6.5	4.7	2.7	2.45	2.85	5.5	6.55
4	4.55	6.55	6.05	8.45	9.45	6.7	4.7	2.7	2.4	2.9	5.4	6.6
5	4.6	6.45	6.05	8.4	9.4	6.9	4.7	2.7	2.4	2.95	5.3	6.7
6	4.6	6.35	6.0	8.8	9.3	7.2	4.7	2.7	2.45	3.0	5.2	6.7
7	4.6	6.25	5.95	9.3	8.8	6.9	4.7	2.7	2.45	3.0	5.2	6.7
8	4.6	6.15	5.95	9.7	8.5	6.8	4.6	2.65	2.5	3.0	5.5	6.7
9	4.65	6.15	6.45	9.8	8.3	6.4	4.6	2.6	2.45	3.1	5.3	6.7
10	4.65	6.05	6.55	9.75	8.3	6.3	4.6	2.6	2.4	3.2	5.7	6.7
11	4.65	5.95	6.65	9.35	8.3	6.2	4.45	2.6	2.35	3.2	6.2	6.65
12	4.65	5.9	6.45	9.05	8.4	6.1	4.35	2.55	2.4	3.1	6.82	6.6
13	4.6	5.75	6.25	8.6	8.2	6.3	4.25	2.6	2.5	3.05	7.90	6.5
14	4.6	5.6	6.05	9.4	7.9	6.3	4.2	2.6	2.55	3.05	10.4	6.4
15	4.6	5.55	6.25	9.2	7.6	6.3	4.1	2.5	2.55	3.05	13.02	6.3
16	4.55	5.5	6.45	8.1	7.55	6.2	4.0	2.45	2.6	3.1	17.34	6.3
17	4.55	5.45	6.35	8.3	7.25	6.2	3.9	2.5	2.6	3.1	19.78	6.2
18	4.55	5.45	6.25	8.4	6.95	6.1	3.8	2.45	2.55	3.3	17.55	6.15
19	4.5	5.65	6.05	8.4	6.55	6.0	3.7	2.5	2.5	3.8	15.62	6.2
20	4.45	6.65	5.85	8.45	6.3	5.8	3.6	2.45	2.55	4.1	12.84	6.3

Daily gage height, in feet, of Yakima River at Kiona, Wash., for 1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
21	4.4	7.35	5.9	8.5	6.2	5.7	3.5	2.5	2.6	4.3	10.62	6.3
22	4.5	7.2	5.95	8.7	6.05	5.5	3.3	2.45	2.6	4.3	9.9	6.9
23	4.65	7.1	5.95	9.6	6.0	5.4	3.2	2.5	2.65	4.3	8.9	8.3
24	4.85	7.0	5.85	9.9	5.9	5.2	3.1	2.5	2.65	4.2	8.5	8.3
25	4.75	6.75	5.9	9.7	5.8	5.2	3.1	2.55	2.68	4.2	8.2	8.2
26	5.75	6.65	5.9	9.2	6.2	5.2	3.0	2.55	2.7	4.1	8.0	8.05
27	5.85	6.45	6.0	9.0	7.25	5.1	2.8	2.55	2.7	4.3	7.7	8.05
28	6.25	6.45	6.35	8.5	7.5	5.0	2.8	2.5	2.7	7.2	7.5	7.7
29	6.3	....	6.55	8.4	7.4	4.9	2.8	2.55	2.7	7.0	7.1	7.6
30	6.35	....	6.9	8.5	7.1	4.8	2.75	2.5	2.7	6.7	6.9	7.3
31	6.25	....	7.3	....	7.0	....	2.8	2.4	....	6.5	....	7.3

Note.—The gage heights from November 15 to 21 were found by plotting several readings a day, and taking the mean from the curve.

Rating table for Yakima River at Kiona, Wash., from October 1, 1905, to December 31, 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.30	90	3.60	620	4.90	1,780	6.40	3,990	9.00	9,590
2.40	120	3.70	690	5.00	1,900	6.60	4,350	10.00	12,100
2.50	150	3.80	760	5.10	2,020	6.80	4,740	11.00	14,950
2.60	180	3.90	835	5.20	2,150	7.00	5,140	12.00	18,150
2.70	210	4.00	910	5.30	2,280	7.20	5,550	13.00	21,900
2.80	245	4.10	990	5.40	2,420	7.40	5,970	14.00	26,350
2.90	280	4.20	1,070	5.50	2,560	7.60	6,390	15.00	31,700
3.00	315	4.30	1,160	5.60	2,700	7.80	6,830	16.00	37,600
3.10	355	4.40	1,250	5.70	2,850	8.00	7,270	17.00	44,000
3.20	400	4.50	1,350	5.80	3,000	8.20	7,710	18.00	50,800
3.30	450	4.60	1,450	5.90	3,160	8.40	8,170	19.00	57,800
3.40	500	4.70	1,560	6.00	3,320	8.60	8,630	20.00	65,100
3.50	555	4.80	1,670	6.20	3,650	8.80	9,110		

Note.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1897-1903 and is well defined.

Monthly discharge of Yakima River at Kiona, Wash., for 1905-6.

[Drainage area, 5,230 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.						
October[a]	4,740	690	2,470	152,000	0.473	0.56
November[a]	2,560	1,560	1,860	111,000	.356	.44
December[a]	1,900	1,450	1,710	105,000	.327	.44
1906.						
January	3,900	1,250	1,850	114,000	.354	.41
February	5,860	2,490	3,840	213,000	.734	.76
March	5,760	3,080	3,710	228,000	.709	.82
April	11,800	7,490	9,400	559,000	1.80	2.01
May	10,700	3,000	6,620	407,000	1.27	1.46
June	5,550	1,670	3,440	205,000	.658	.73
July	1,670	228	923	56,800	.176	.20
August	245	120	172	10,600	.033	.04
September	210	105	162	9,640	.031	.03
October	5,550	228	1,120	68,900	.214	.25
November	63,500	2,150	12,400	738,000	2.37	2.64
December	7,940	3,560	5,010	308,000	.958	1.10
The year	63,500	105	4,050	2,920,000	.776	10.45

[a] These values supersede those published in Water-Supply Paper No. 178, which were in error. The published gage heights for 1905 were in error as follows: October 21 to November 9, 0.7 foot too high; November 10 to 29, 0.2 foot too high; November 30 to December 19, 0.3 foot too high, and from December 19 to 23, 0.35 foot too high.

Note.—Values for 1905 and 1906 are rated as good.

YAKIMA RIVER NEAR RICHLAND, WASH.

This station was established July 28, 1906, for the purpose of determining the amount of water wasted into Columbia River. It is maintained only during the irrigating season. It is located at Yakima Ferry, near the mouth of Yakima River, and below the headgate of the Amon Canal, the last diversion.

The channel is straight, the banks are high and clean. The bed of the stream is composed of gravel and bowlders.

Measurements are made by wading at any convenient place near the gage.

The gage, which was read during the season by J. E. See, is a 1 by 6 inch board bolted to a large bowlder in midstream, 500 feet below the ferry. The bench mark is a cross, marked B. M., on a large, round bowlder in the channel, at right angles to the direction of current from the old cribworks on the right bank, where an old water lift wheel was located; elevation, 5.05 feet above the datum of the gage.

Discharge measurements of Yakima River near Richland, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
July 28	W. C. Muldrow	89	122	1.46	175
August 17	J. C. Stevens	16	12	.63	9.4
October 13	W. C. Muldrow	100	140	1.55	195

Daily gage height, in feet, of Yakima River near Richland, Wash., for 1906.

Day.	July.	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.
1	......	1.25	0.6	0.8	12	......	0.7	0.6	1.6	23	......	0.6	0.6	......
2	......	1.15	.6	.85	13	......	.7	.6	1.55	24	......	.6	.6	......
3	......	1.1	.6	1.0	14	......	.65	.6	1.52	25	......	.6	.75	......
4	......	1.5	.6	1.25	15	......	.65	.6	1.6	26	......	.6	.8	......
5	......	1.0	.6	1.2	16	......	.65	.6	1.7	27	......	.6	.88	......
6	......	0.9	.6	1.35	17	......	.65	.6	1.75	28	1.5	.6	.8	......
7	......	.8	.6	1.3	18	......	.6	.6	1.78	29	1.4	.6	.8	......
8	......	.75	.6	1.38	19	......	.6	.6	1.9	30	1.35	.6	.8	......
9	......	.7	.6	1.28	20	......	.6	.6	2.8	31	1.25	.6	......	......
10	......	.75	.6	1.5	21	......	.6	.6	......					
11	......	.7	.6	1.55	22	......	.6	.6	......					

Rating table for Yakima River near Richland, Wash., from July 28, 1906, to October 19, 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.60	8	0.90	31	1.20	87	1.50	185	1.80	340
0.70	13	1.00	46	1.30	114	1.60	235	1.90	400
0.80	21	1.10	65	1.40	145	1.70	280		

NOTE.—The above table is based on 3 discharge measurements made during 1906 and is not well defined.

Monthly discharge of Yakima River near Richland, Wash., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
July (28-31)	185	100	140	1,110
August	185	8	24.6	1,510
September	29	8	10.7	637
October (1-19)	400	21	178	6,710
The period				9,970

NOTE.—Values are rated as fair.

LAKE KEECHELUS NEAR MARTIN, WASH.

This station was established January 12, 1906, to obtain the fluctuations of the lake surface and the amount of stored water. It is located at the foot of the lake, 4 miles northeast of Martin, Wash., on the State road over Snoqualmie Pass.

All gage heights for 1906 refer to the level of the sill of the outlet tunnel of the dam, which is 2,457.00 feet above sea level. The bench mark is a spike in the root of a stump on the right bank of the outlet near the abutment of the dam; elevation, 16.05 feet above the datum of the gage and 2,473.05 above sea level.

Daily gage height, in feet, of Lake Keechelus near Martin, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		1.72	1.48	1.73	3.17	2.47	1.73	0.82	0.40	0.44	2.22	3.12
2		1.62	1.41	1.86	3.57	2.40	1.73	.80	.38	.46	2.06	3.31
3		1.53	1.33	1.84	3.54	2.40	1.73	.78	.37	.54	2.02	3.41
4		1.43	1.28	1.84	3.50	2.63	1.70	.78	.36	.91	1.99	3.59
5		1.35	1.25	1.91	3.39	2.58	1.68	.76	.35	.93	1.94	3.85
6		1.32	1.20	2.10	3.16	2.51	1.64	.75	.32	.92	2.08	4.12
7		1.31	1.16	2.37	3.02	2.44	1.58	.75	.36	.88	2.22	4.59
8		1.30	1.16	2.53	2.96	2.34	1.52	.74	.36	.94	2.44	4.82
9		1.28	1.22	2.58	3.03	2.24	1.47	.73	.36	.99	2.64	5.01
10		1.26	1.30	2.53	3.25	2.19	1.44	.72	.36	1.00	3.16	5.09
11		1.24	1.33	2.42	3.30	2.15	1.43	.70	.33	.97	3.70	5.20
12	0.86	1.22	1.36	2.30	3.28	2.22	1.37	.70	.32	1.01	3.92	4.66
13	.85	1.20	1.34	2.16	3.09	2.17	1.34	.69	.32	1.04	5.73	4.21
14	.83	1.18	1.32	2.06	2.90	2.14	1.31	.64	.52	1.10	6.09	4.01
15	.77	1.16	1.28	2.04	2.95	2.11	1.26	.64	.54	1.32		3.93
16	.92	1.16	1.24	2.00	2.84	2.08	1.24	.63	.52	1.67		3.81
17	.94	1.17	1.24	2.25	2.73	2.03	1.21	.62	.50	2.22		4.03
18	1.00	1.20	1.18	2.32	2.56	2.00	1.17	.62	.46	2.64		4.01
19		1.70	1.18	2.34	2.43	1.96	1.13	.61	.42	2.64		4.41
20		1.84	1.13	2.46	2.36	1.94	1.10	.60	.40	2.50		4.91
21	1.46	1.87	1.10	2.76	2.30	1.94	1.06	.60	.37	2.27		4.95
22	1.57	1.86	1.08	3.04	2.28	1.99	1.04	.58	.35	2.16		4.75
23	1.77	1.84	1.08	3.07	2.21	1.96	1.02	.56	.34	2.11		4.52
24	1.84	1.84	1.04	2.98	2.17	1.92	.97	.54	.34	2.06		4.31
25	1.87	1.80	1.02	2.92	2.26	1.90	.94	.52	.40	2.17		4.29
26	2.30	1.75	1.04	2.88	2.65	1.86	.92	.50	.47	2.27		4.69
27	2.20	1.67	1.08	2.82	2.69	1.86	.90	.49	.48	2.32		5.02
28	2.14	1.58	1.11	2.80	2.62	1.83	.88	.48	.50	2.47		5.32
29	2.03		1.16	2.90	2.53	1.84	.86	.46	.48	2.67		5.63
30	1.93		1.25	3.02	2.56	1.82	.85	.43	.45	2.57	3.12	5.95
31	1.82		1.56		2.52		.84	.41		2.37		6.22

KACHESS LAKE NEAR EASTON, WASH.

This station was established September 20, 1905, in order to determine the amount of storage in Kachess Lake. The datum of the gage is the same as during 1905.

Daily gage height, in feet, of Kachess Lake, near Easton, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.25	2.2	1.95	1.7	3.6	5.6	5.4	3.25	1.35	0.55	2.45	3.85
2	1.2	2.2	1.9	1.8	3.8	5.65	5.3	3.2	1.3	.6	2.35	3.6
3	1.15	2.15	1.85	1.9	3.8	5.8	5.25	3.2	1.2	.6	2.3	3.25
4	1.2	2.15	1.8	2.0	3.8	6.0	5.2	3.15	1.1	.65	2.2	3.2
5	1.15	2.15	1.8	2.0	3.75	6.05	5.1	3.15	1.1	.65	2.2	3.0
6	1.25	2.1	1.7	2.1	3.7	6.1	5.05	3.15	1.0	.65	2.4	2.85
7	1.15	2.05	1.6	2.25	3.6	6.1	5.0	3.1	1.0	.65	2.5	2.9
8	1.15	2.05	1.6	2.5	3.5	6.05	4.9	3.1	.95	.65	2.65	2.8
9	1.2	2.0	1.6	2.65	3.5	6.0	4.8	3.05	.9	.6	2.75	2.6
10	1.15	2.0	1.6	2.7	3.6	6.0	4.7	3.0	.85	.65	3.1	2.5
11	1.1	2.05	1.6	2.7	3.8	5.95	4.6	2.9	.8	.65	3.4	2.4
12	1.1	1.95	1.6	2.6	4.0	5.95	4.5	2.85	.75	.65	3.92	2.3
13	1.15	1.9	1.6	2.6	4.1	5.9	4.45	2.75	.75	.65	5.38	2.2
14	1.15	1.9	1.6	2.6	4.2	5.9	4.35	2.7	.8	.7	8.18	2.15
15	1.15	1.8	1.55	2.6	4.4	5.85	4.25	2.65	.75	.75	9.46	2.1
16	1.1	1.7	1.55	2.65	4.6	5.85	4.2	2.55	.7	.85	9.34	2.05
17	1.1	1.7	1.55	2.7	4.7	5.75	4.1	2.5	.7	1.1	8.72	1.95
18	1.1	1.85	1.55	2.7	4.8	5.7	4.0	2.4	.7	1.25	8.1	1.9
19	1.1	1.9	1.55	2.8	5.0	5.7	3.9	2.3	.65	1.3	7.6	2.0
20	1.1	1.95	1.5	2.8	5.15	5.7	3.8	2.2	.6	1.3	7.1	2.15
21	1.15	1.9	1.5	3.0	5.25	5.75	3.7	2.1	.6	1.3	6.6	2.2
22	1.15	2.0	1.5	3.3	5.35	5.8	3.6	2.05	.6	1.3	6.2	2.25
23	1.3	1.9	1.4	3.4	5.4	5.8	3.5	2.0	.6	1.25	5.8	2.2
24	1.35	1.85	1.4	3.5	5.45	5.8	3.5	1.9	.55	1.3	5.4	2.15
25	1.45	1.95	1.5	3.5	5.45	5.8	3.4	1.9	.6	1.4	5.3	2.1
26	1.65	2.0	1.4	3.5	5.45	5.75	3.4	1.8	.55	2.3	4.9	2.1
27	1.7	1.95	1.4	3.5	5.5	5.65	3.35	1.7	.6	2.7	4.5	2.1
28	1.9	1.95	1.4	3.5	5.5	5.6	3.3	1.7	.6	2.7	4.4	2.05
29	2.0	......	1.5	3.5	5.55	5.5	3.3	1.6	.55	2.6	4.2	2.0
30	2.15	......	1.5	3.55	5.55	5.45	3.3	1.5	.5	2.6	4.0	1.95
31	2.15	......	1.5	......	5.5	......	3.3	1.45	......	2.45	......	1.9

KACHESS RIVER NEAR EASTON, WASH.

This station was established October 14, 1903. It is located 2 miles northwest of Easton, Wash., and one-half mile below the foot of Lake Kachess, at the outlet of which a dam has been constructed by the Cascade Canal Company. This dam controls the flow. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 78, where are given also references to publications that contain data for previous years.

Discharge measurements of Kachess River near Easton, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 16	J. C. Stevens	70	113	3.86	215
May 1	W. C. Muldrow	76	229	5.45	732
July 16	do	69	120	4.01	256
August 11	do	68	94	3.62	156
August 23	do	68	97	3.63	149
September 24	do	64	67	3.23	74
October 29	Muldrow and McGlashan	74	164	4.60	428
November 26	W. C. Muldrow	76	230	5.50	722

Daily gage height, in feet, of Kachess River near Easton, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.7	4.2	4.1	3.95	5.45	3.95	4.25	3.3	3.55	3.2	4.4	5.1
2	3.65	4.2	4.0	4.0	5.5	3.9	4.2	3.3	3.6	3.25	4.3	5.0
3	3.65	4.2	4.0	4.05	5.5	4.0	4.15	3.25	3.6	3.3	4.2	4.9
4	3.65	4.15	4.0	4.1	5.5	4.1	4.2	3.2	3.6	3.35	4.0	4.9
5	3.65	4.2	4.0	4.1	5.45	4.2	4.2	3.2	3.55	3.35	3.2	4.8
6	3.7	4.15	3.9	4.2	5.4	4.3	4.25	3.2	3.5	3.35	3.2	4.6
7	3.65	4.15	3.9	4.35	5.4	4.3	4.3	3.2	3.5	3.35	3.3	4.6
8	3.65	4.15	3.9	4.45	5.3	4.25	4.2	3.25	3.5	3.3	3.3	4.5
9	3.7	4.1	3.9	4.55	5.3	4.6	4.15	3.6	3.45	3.3	3.35	4.45
10	3.6	4.1	3.9	4.6	5.4	4.6	4.1	3.65	3.45	3.3	3.4	4.4
11	3.6	4.1	3.9	4.55	4.5	4.6	4.05	3.6	3.4	3.3	3.45	4.35
12	3.6	4.1	3.9	4.5	4.25	4.55	4.0	3.6	3.4	3.3	3.72	4.35
13	3.6	4.05	3.9	4.5	4.2	4.55	4.0	3.6	3.35	3.3	4.68	4.3
14	3.6	4.0	3.9	4.5	3.7	4.5	4.1	3.6	3.35	3.35	6.64	4.2
15	3.6	3.95	3.9	4.5	3.7	4.5	4.05	3.6	3.35	3.4	7.85	4.15
16	3.6	3.9	3.9	4.55	3.8	4.45	4.0	3.65	3.3	3.45	8.0	4.1
17	3.6	3.9	3.9	4.6	3.7	4.45	4.0	3.65	3.3	3.55	7.82	4.1
18	3.6	3.95	3.85	4.6	3.65	4.4	3.95	3.75	3.3	3.65	7.5	4.05
19	3.6	4.0	3.85	4.65	3.6	4.1	3.85	3.75	3.3	3.7	7.2	4.05
20	3.6	4.05	3.8	4.65	3.6	4.1	3.8	3.7	3.25	3.7	6.8	4.1
21	3.65	4.05	3.8	4.8	3.65	4.0	3.85	3.7	3.25	3.7	6.6	4.15
22	3.65	4.15	3.8	5.0	3.65	3.95	3.8	3.65	3.25	3.7	6.4	4.25
23	3.7	4.1	3.75	5.05	3.6	3.9	3.7	3.7	3.2	3.65	6.1	4.2
24	3.8	4.1	3.75	5.15	3.6	3.9	3.4	3.6	3.2	3.65	5.85	4.2
25	3.85	4.1	3.8	5.2	4.2	4.5	3.3	3.7	3.3	3.7	5.7	4.15
26	4.0	4.15	3.75	5.2	4.55	4.55	3.35	3.7	3.25	4.45	5.5	4.15
27	4.0	4.1	3.75	5.2	4.55	4.55	3.45	3.65	3.25	4.8	5.3	4.15
28	4.1	4.1	3.75	5.2	4.6	4.5	3.35	3.6	3.25	4.7	5.3	4.1
29	4.1	....	3.8	5.3	4.6	4.5	3.3	3.7	3.2	4.6	5.2	4.1
30	4.1	....	3.8	5.4	4.6	4.35	3.25	3.65	3.2	4.6	5.15	4.05
31	4.15	....	3.81	....	4.55	....	3.3	3.6	....	4.4	....	4.0

Note.—Gage heights for November 12 to 17 were found by plotting several readings a day and taking the mean from the curve.

Rating table for Kachess River near Easton, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
3.20	62	4.00	240	4.80	475	5.60	780	6.80	1,440
3.30	80	4.10	266	4.90	510	5.70	830	7.00	1,560
3.40	98	4.20	294	5.00	545	5.80	880	7.20	1,690
3.50	118	4.30	322	5.10	580	5.90	930	7.40	1,830
3.60	140	4.40	350	5.20	615	6.00	980	7.60	1,980
3.70	164	4.50	380	5.30	655	6.20	1,090	7.80	2,140
3.80	188	4.60	410	5.40	695	6.40	1,200	8.00	2,300
3.90	214	4.70	442	5.50	735	6.60	1,320		

Note.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1906 and is well defined below gage height 5.5 feet.

Monthly discharge of Kachess River near Easton, Wash., for 1906.

[Drainage area, 63 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	280	140	173	10,600	2.75	3.17
February	294	214	263	14,600	4.17	4.34
March	266	176	206	12,700	3.27	3.77
April	695	227	434	25,800	6.89	7.69
May	735	140	401	24,700	6.37	7.34
June	410	214	325	19,300	5.16	5.76
July	322	71	211	13,000	3.35	3.86
August	176	62	131	8,060	2.08	2.40
September	140	62	92.8	5,520	1.47	1.64
October	475	62	168	10,300	2.67	3.08
November	2,300	62	798	47,500	12.67	14.14
December	580	240	337	20,700	5.35	6.17
The year	2,300	62	295	213,000	4.68	63.36

Note.—Values are rated as follows: January to March and July to October, good; remainder of year, excellent.

CLEALUM RIVER NEAR ROSLYN, WASH.

This station was established October 10, 1903. It is located 1,000 feet below the outlet of Lake Clealum. It is 2½ miles northwest of Roslyn and 6½ miles northwest of Clealum, Wash. On March 17, 1906, the gage was lowered to the same datum as was used prior to August 28, 1905. All gage heights of 1906 refer to this datum, 17.40 feet below the bench mark, which is a large spike driven into a root on the downstream side of the blazed tree on the left bank to which the cable is fastened. The gage was read during 1906 by Mark Barkwell, Mrs. Samuel Davis, and employees of the United States Reclamation Service . The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 80, where are given also references to publications that contain data for previous years.

Discharge measurements of Clealum River near Roslyn, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 17[a]	J. C. Stevens	124	720	2.35	526
May 3	W. C. Muldrow	148	1,220	5.98	3,370
July 18[a]	do	125	753	2.90	774
August 13[b]	do	80	139	1.96	443
August 24[b]	Stevens and Muldrow	82	114	1.58	264
October 31	Muldrow and McGlashan	128	883	3.50	1,150
November 27	W. C. Muldrow	125	786	3.01	780

[a] Large amount of dead water.

[b] Measured by wading.

Daily gage height, in feet, of Clealum River near Roslyn, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.8	3.1	2.45	4.0	6.0	4.1			1.6	1.7	3.2	2.7
2	1.75	3.2	2.4	4.0	6.1	4.0			1.6	1.7	3.1	2.6
3	1.72	3.15	2.35	3.9	6.0	4.1			1.6	1.8	2.9	2.5
4	1.72	3.1	2.3	3.8	6.0	4.7			1.6	1.8	2.8	2.4
5	1.7	3.0	2.25	3.9	5.8	4.8		2.0	1.6	1.9	2.7	2.4
6	1.7	2.9	2.2	4.4	5.3	4.5		2.0	1.6	1.9	2.7	2.4
7	1.75	2.8	2.2	4.7	5.0	4.1		2.0	1.6	1.9	2.8	2.4
8	1.72	2.7	2.2	4.9	4.9	3.9		2.0	1.6	1.9	2.9	2.3
9	1.75	2.6	2.3	4.8	5.0	3.8		2.0	1.6	1.8	2.9	2.3
10	1.75	2.55	2.4	4.5	5.5			2.0	1.7	1.8	3.2	2.3
11	1.75	2.5	2.5	4.3	5.7			2.0	1.7	1.8	4.0	2.3
12	1.72	2.4	2.5	4.0	5.6			2.0	1.7	1.9	4.2	2.3
13	1.72	2.4	2.58	3.8	5.1			2.0	1.7	1.9	6.3	2.2
14	1.7	2.32	2.5	3.7	4.8			2.0	1.7	1.9	11.1	2.2
15	1.7	2.3	2.5	3.7	4.7			2.0	1.7	2.0	14.0	2.2
16	1.7	2.25	2.45	3.9	4.6			2.0	1.7	2.2	11.6	2.2
17	1.7	2.2	2.4	4.2	4.2			2.0	1.7	2.5	8.6	2.2
18	1.7	2.4	2.3	4.3	4.0			2.0	1.7	2.7	6.6	2.2
19	1.7	2.5	2.28	4.3	3.9		2.9	1.9	1.7	2.8	5.4	2.3
20	1.7	2.7	2.1	4.4	3.8			1.9	1.6	2.8	4.8	2.3
21	1.7	2.8	2.0	4.9	3.7			1.1	1.6	2.7	4.2	2.3
22	1.8	2.8	2.0	5.9	3.7		2.1	1.1	1.6	2.6	3.9	2.4
23	1.8	2.8	2.0	6.1	3.7			1.1	1.6	2.5	3.6	2.5
24	2.0	2.7	1.8	5.7	3.8			1.1	1.6	2.5	3.4	2.5
25	2.3	2.7	1.8	5.2	3.9			1.1	1.7	2.5	3.3	2.5
26	2.7	2.7	1.9	4.9	4.5			1.4	1.8	6.7	3.0	2.5
27	2.9	2.6	2.0	4.7	4.9			1.5	1.8	6.6	3.0	2.5
28	3.0	2.52	2.05	4.7	4.8			1.5	1.8	5.4	2.9	2.4
29	3.0		2.1	5.0	4.4		2.0	1.5	1.9	4.5	2.8	2.4
30	3.0		2.5	5.4	4.2			1.6	1.9	3.9	2.7	2.4
31	3.0		3.4		4.2			1.6		3.5		2.4

Rating table for Clealum River near Roslyn, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.10	140	2.20	460	3.30	940	4.80	1,970	6.80	4,160
1.20	165	2.30	495	3.40	995	5.00	2,150	7.00	4,400
1.30	190	2.40	530	3.50	1,050	5.20	2,350	8.00	5,800
1.40	215	2.50	570	3.60	1,110	5.40	2,550	9.00	7,340
1.50	240	2.60	610	3.70	1,170	5.60	2,760	10.00	9,040
1.60	270	2.70	650	3.80	1,230	5.80	2,980	11.00	10,900
1.70	300	2.80	695	3.90	1,295	6.00	3,200	12.00	12,940
1.80	330	2.90	740	4.00	1,360	6.20	3,440	13.00	15,200
1.90	360	3.00	785	4.20	1,500	6.40	3,680	14.00	17,700
2.00	390	3.10	835	4.40	1,640	6.60	3,920		
2.10	425	3.20	885	4.60	1,800				

Note.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903–1906 and is well defined between gage heights 1.4 feet and 6.0 feet.

Monthly discharge of Clealum River near Roslyn, Wash., for 1906.

[Drainage area, 205 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	785	300	404	24,800	1.97	2.27
February	885	460	644	35,800	3.14	3.27
March	995	330	494	30,400	2.41	2.78
April	3,320	1,170	1,800	107,000	8.78	9.80
May	3,320	1,170	2,020	124,000	9.85	11.36
June 1–9	1,970	1,230	1,530	27,300	7.46	2.50
August 5–31	390	140	309	16,500	1.51	1.52
September	360	270	293	17,400	1.43	1.60
October	4,040	300	831	51,100	4.06	4.68
November	17,700	650	2,650	158,000	12.92	14.40
December	650	460	522	32,100	2.54	2.93
The period				622,000		

Note.—Values are rated as follows: April to June, excellent; remainder of period, good.

NACHES RIVER NEAR NILE, WASH.

This station was established June 23, 1904. It is located 1⅜ miles above the highway bridge, 23 miles northwest of North Yakima, and 8 miles southeast of Nile, Wash. The station is 1¾ miles above the junction of Naches and Tieton rivers.

On November 15, 1906, the gage was destroyed by a flood. Gage heights after that date were taken from a temporary slanting gage, and have been reduced to the same datum as the old gage. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 82, where are given also references to publications that contain data for previous years.

Discharge measurements of Naches River near Nile, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 27	J. C. Stevens	189	360	4.43	1,110
May 23	W. C. Muldrow	190	409	4.80	1,530
June 23	do	192	365	4.50	1,250
July 14	do	188	268	4.00	626
August 16	do	182	174	3.46	253
November 15[a]	do	246	1,730	10.30	22,000
December 9	do	196	377	4.00	1,270

[a] Computed from slope measurement and surface floats.

Daily gage height, in feet, of Naches River near Nile, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.7	4.3	4.3	5.3	6.0	4.9	4.4	3.6	3.4	3.4	3.9	3.35
2	3.9	4.3	4.2	5.1	5.9	4.9	4.4	3.6	3.4	3.4	3.9	3.35
3	4.0	4.3	4.2	5.0	6.0	5.0	4.4	3.6	3.4	3.4	3.9	3.22
4	3.8	4.25	4.15	5.1	6.0	5.1	4.4	3.6	3.4	3.5	3.9	3.22
5	3.8	4.2	4.1	5.4	5.9	5.0	4.3	3.6	3.4	3.5	3.9	3.22
6	3.8	4.15	4.1	5.7	5.7	4.9	4.3	3.6	3.4	3.5	3.8	3.09
7	3.8	4.2	4.2	5.9	5.6	4.8	4.3	3.6	3.4	3.5	3.9	3.74
8	3.75	4.2	4.3	6.0	5.7	4.7	4.3	3.6	3.4	3.5	4.3	3.87
9	3.8	4.15	4.4	5.9	5.7	4.7	4.2	3.6	3.5	3.5	4.3	3.74
10	3.8	4.1	4.5	5.7	5.8	4.7	4.2	3.6	3.5	3.5	4.5	3.61
11	3.7	4.05	4.4	5.6	5.9	4.7	4.2	3.5	3.5	3.5	5.0	3.48
12	3.75	4.1	4.3	5.4	5.8	4.9	4.1	3.5	3.5	3.5	5.18	3.48
13	3.7	4.0	4.3	5.3	5.5	4.8	4.1	3.5	3.5	3.5	7.12	3.35
14	3.8	4.0	4.2	5.3	5.4	4.8	4.0	3.5	3.5	3.5	10.14	3.35
15	3.75	3.95	4.1	5.4	5.4	4.7	4.0	3.5	3.6	3.6	10.14	3.35
16	3.7	4.0	4.1	5.5	5.2	4.7	4.0	3.5	3.6	3.8	9.04	3.22
17	3.7	4.0	4.2	5.5	5.1	4.7	4.0	3.5	3.5	4.0	6.84	3.22
18	3.8	4.1	4.3	5.6	5.0	4.6	3.9	3.5	3.5	4.0	5.6	3.22
19	3.75	4.9	4.3	5.5	4.9	4.6	3.9	3.5	3.5	4.0	5.2	3.22
20	3.8	5.0	4.2	5.6	4.9	4.6	3.9	3.5	3.5	3.9	5.08	3.48
21	3.7	4.9	4.1	5.8	4.8	4.6	3.8	3.4	3.5	3.8	4.84	4.48
22	3.7	4.7	4.1	6.1	4.9	4.5	3.8	3.4	3.5	3.8	4.6	4.48
23	3.8	4.6	4.1	6.2	4.8	4.5	3.8	3.5	3.4	3.7	4.36	4.24
24	4.0	4.6	4.1	6.0	4.8	4.5	3.8	3.5	3.4	3.7	4.36	4.24
25	4.1	4.5	4.2	5.8	4.9	4.5	3.8	3.5	3.4	3.7	4.12	4.12
26	4.1	4.4	4.2	5.7	5.4	4.6	3.7	3.5	3.5	4.2	4.0	4.0
27	4.1	4.4	4.6	5.6	5.3	4.5	3.7	3.5	3.5	4.4	3.87	3.87
28	4.05	4.3	4.6	5.5	5.2	4.5	3.7	3.5	3.5	4.3	3.61	3.74
29	4.0	....	4.7	5.6	5.1	4.4	3.7	3.4	3.5	4.2	3.61	3.74
30	4.1	....	4.8	5.7	5.0	4.4	3.7	3.4	3.5	4.1	3.48	3.61
31	4.2	....	5.2	....	4.9	....	3.7	3.4	....	4.0	....	3.48

NOTE.—Gage lengths for November 12 to 17 were found by plotting several readings a day and taking the mean from the curve.

Rating table for Naches River near Nile, Wash., from January 1, 1905, to November 15, 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
3.40	235	4.30	960	5.20	2,380	6.20	4,740	8.00	10,700
3.50	280	4.40	1,090	5.30	2,580	6.40	5,300	8.20	11,520
3.60	330	4.50	1,230	5.40	2,780	6.60	5,880	8.40	12,360
3.70	390	4.60	1,380	5.50	3,000	6.80	6,480	8.60	13,240
3.80	460	4.70	1,530	5.60	3,220	7.00	7,100	8.80	14,160
3.90	540	4.80	1,690	5.70	3,460	7.20	7,740	9.00	15,100
4.00	630	4.90	1,850	5.80	3,700	7.40	8,420	10.00	20,320
4.10	730	5.00	2,020	5.90	3,960	7.60	9,140		
4.20	840	5.10	2,200	6.00	4,220	7.80	9,900		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905-6 and is well defined below gage height 5 feet.

Monthly discharge of Naches River near Nile, Wash., for 1906.

[Drainage area, 636 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	840	390	513	31,500	0.807	0.93
February	2,020	535	1,010	56,100	1.59	1.66
March	2,380	730	996	61,200	1.57	1.81
April	4,740	2,020	3,250	193,000	5.11	5.70
May	4,220	1,690	2,810	173,000	4.42	5.10
June	2,200	1,090	1,530	91,000	2.41	2.69
July	1,090	390	676	41,600	1.06	1.22
August	330	235	289	17,800	.454	.52
September	330	235	267	15,900	.420	.47
October	1,090	235	458	28,200	.720	.83
November 1-15	21,100	460	4,060	121,000	6.38	3.56
The period				800,000		

NOTE.—Values are rated as follows: January to May and November, good; June to October, excellent.

NACHES RIVER NEAR NORTH YAKIMA, WASH.

The original station on Naches River was established August 14, 1893, at a point a few hundred yards above the mouth of the river, near the bridge of the Northern Pacific Railway.

On April 24, 1906, a standard chain gage was installed at the highway bridge above the cable; length of chain, 27.10 feet. After April 28, 1906, this gage was read by Mrs. A. M. Cole. The flood of November 16, 1906, swept out this gage with the bridge and changed the channel. A temporary vertical gage, installed November 22, at the same datum, was read during the remainder of the year. The bench mark is a brass plug in the top of the concrete-filled steel pier, 10 feet north of the gage; elevation, 21.74 feet above the datum of the gage and 1,093.87 feet above sea level.

The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 86, where are given also references to publications that contain data for previous years.

Discharge measurements of Naches River near North Yakima, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 26	Stevens and Muldrow	130	387	[a] 5.35	970
April 3	W. C. Muldrow	143	576	[a] 6.15	2,140
April 25	do	158	644	6.45	3,790
May 28	do	142	452	5.67	2,440
June 21	do	132	307	4.48	1,280
July 10	do	127	248	4.00	961
August 20	J. C. Stevens	57	33	2.10	40
October 26	Muldrow and McGlashan	131	322	4.40	1,230
November 14[b]	W. C. Muldrow	270	1,820	11.50	24,300
November 22	do	240	923	8.20	3,590

[a] Gage height from inclined gage; other gage heights are from chain gage.
[b] Measured by floats.

Daily gage height, in feet, of Naches River near North Yakima, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.3	5.2	5.3	6.35	6.9	5.2	4.1	2.6	2.0	2.1	3.6	7.5
2	4.3	5.2	5.2	6.3	6.9	5.1	4.0	2.5	2.0	2.4	3.5	7.5
3	4.4	5.2	5.2	6.1	7.0	5.6	4.1	2.3	2.0	2.3	3.5	7.4
4	4.4	5.2	5.1	6.3	7.1	5.7	4.2	2.3	2.1	2.4	3.6	7.4
5	4.4	5.2	5.0	6.6	6.7	5.4	4.2	2.5	1.9	2.5	3.5	7.4
6	4.4	5.2	5.0	7.0	6.0	5.1	4.2	2.3	2.0	2.5	3.4	7.5
7	4.3	5.1	5.0	7.3	6.4	4.9	4.4	2.4	2.4	2.4	3.6	7.5
8	4.3	5.1	5.2	....	6.2	4.8	4.3	2.2	2.5	2.5	4.8	7.7
9	4.3	5.0	5.5	7.3	6.4	4.8	4.1	2.3	2.5	2.5	4.4	7.7
10	4.3	5.0	5.5	7.1	6.8	4.7	3.9	2.2	2.3	2.5	4.8	7.6
11	4.3	4.95	5.4	6.9	6.8	4.7	4.0	2.2	2.3	2.4	5.8	7.5
12	4.2	4.9	5.3	6.6	6.6	5.0	3.9	2.3	2.2	2.5	5.6	7.4
13	4.2	4.9	5.3	6.5	6.2	5.0	3.8	2.3	2.0	2.5	9.1	7.3
14	4.2	4.8	5.3	6.6	5.9	4.8	3.7	2.4	2.3	2.5	11.15	7.3
15	4.2	4.8	5.2	....	6.0	4.7	3.7	2.3	2.7	2.7	10.7	7.2
16	4.2	4.8	5.2	6.7	5.8	4.8	3.8	2.4	2.5	2.7	10.7	7.3
17	4.2	4.7	5.2	6.7	5.6	4.8	3.5	2.2	2.4	3.6	9.7	7.3
18	4.2	5.5	5.1	6.7	5.2	4.7	3.4	2.1	2.3	3.6	(a)	7.2
19	4.2	6.3	5.1	6.8	5.0	4.6	3.4	2.0	2.2	3.4	....	7.2
20	4.2	6.2	5.1	6.8	5.0	4.5	3.2	2.1	2.3	3.3	....	7.3
21	4.2	6.1	5.1	7.1	4.7	4.5	3.1	2.1	2.3	3.3	....	8.5
22	4.2	5.9	5.0	....	4.8	4.5	3.0	2.1	2.3	3.2	....	8.6
23	4.4	5.8	5.0	7.6	4.9	4.4	3.1	2.1	2.3	3.0	....	8.3
24	4.5	5.6	5.0	7.3	5.0	4.3	3.0	1.9	2.4	3.0	....	8.3
25	4.7	5.55	5.0	7.1	5.1	4.4	2.8	2.1	2.4	3.0	7.9	8.1
26	4.9	5.5	5.0	7.0	6.2	4.6	2.9	2.0	2.3	4.0	7.8	8.0
27	4.9	5.4	5.2	6.8	6.0	4.4	2.8	2.0	2.2	4.8	7.7	7.9
28	4.9	5.3	5.8	5.9	5.9	4.2	2.7	2.0	2.4	4.4	7.6	7.9
29	4.9	....	5.9	6.1	5.7	4.1	3.1	2.5	2.2	4.0	7.6	7.9
30	4.9	....	6.0	6.4	5.5	4.0	2.8	2.0	2.2	3.8	7.5	7.8
31	5.1	....	6.4	....	5.4	....	2.7	2.2	....	3.6	....	7.7

[a] Gage and bridge destroyed by flood.

Rating tables for Naches River near North Yakima, Wash.

JANUARY 1 TO APRIL 29, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
4.20	285	4.90	650	5.60	1,280	6.30	2,190	7.00	3,360
4.30	325	5.00	720	5.70	1,390	6.40	2,340	7.10	3,540
4.40	370	5.10	800	5.80	1,510	6.50	2,500	7.20	3,730
4.50	420	5.20	880	5.90	1,630	6.60	2,660	7.30	3,920
4.60	470	5.30	970	6.00	1,760	6.70	2,830	7.40	4,110
4.70	525	5.40	1,070	6.10	1,900	6.80	3,000	7.50	4,300
4.80	585	5.50	1,170	6.20	2,040	6.90	3,180	7.60	4,500

APRIL 28 TO NOVEMBER 14, 1906.[b]

1.10	5	2.10	45	3.10	365	4.20	1,055	6.20	3,350
1.20	7	2.20	60	3.20	415	4.40	1,210	6.40	3,670
1.30	9	2.30	75	3.30	470	4.60	1,380	6.60	4,000
1.40	11	2.40	95	3.40	525	4.80	1,570	6.80	4,340
1.50	14	2.50	120	3.50	585	5.00	1,780	7.00	4,700
1.60	17	2.60	150	3.60	645	5.20	2,000	8.00	6,880
1.70	21	2.70	185	3.70	710	5.40	2,240	9.00	10,100
1.80	25	2.80	225	3.80	775	5.60	2,500	10.00	14,800
1.90	30	2.90	270	3.90	840	5.80	2,770	11.00	20,900
2.00	35	3.00	315	4.00	910	6.00	3,050		

[a] This table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905-6 and is fairly well defined below gage height 6.2 feet.

[b] This table is applicable only for open-channel conditions. It is based on 7 discharge measurements made during 1906 and is well defined between gage heights 2.0 feet and 6.5 feet.

Monthly discharge of Naches River near North Yakima, Wash., for 1906.

[Drainage area, 1,120 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	800	285	395	24,300	0.353	0.41
February	2,190	525	1,030	57,200	.920	.96
March	2,340	720	982	60,400	.877	1.01
April	4,500	1,900	3,120	186,000	2.79	3.11
May	4,890	1,470	3,040	187,000	2.71	3.12
June	2,630	910	1,550	92,200	1.38	1.54
July	1,210	185	646	39,700	.577	.67
August	150	30	67.6	4,160	.060	.07
September	185	30	74.8	4,450	.067	.07
October	1,570	45	386	23,700	.345	.40
November 1-14	21,900	525	3,300	91,600	2.95	1.54
The period				771,000		

NOTE.—Values are rated as follows: January to April, good; July to November, fair.

BUMPING RIVER NEAR NILE, WASH.

This station was established June 13, 1906, for the Tieton project of the United States Reclamation Service. It is located at the outlet of Bumping Lake.

Discharge measurements are made by wading.

The gage, which was read during a part of 1906 by employees of the Reclamation Service, is a vertical staff fastened to the stump of a tree, at the point where the trail crosses the river, 2,000 feet below the lake.

Discharge measurements of Bumping River near Nile, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
June 13	W. C. Muldrow	110	193	1.40	352
July 9	C. E. Hewitt	120	171	1.02	266
July 14	do	116	141	.76	198
July 18	do	115	126	.63	161
July 23	do	115	114	.52	136
July 28	do	115	105	.44	120
November 14[a]	W. C. Muldrow	140	900	7.00	6,000
December 7	do	110	201	1.50	407

[a] Computed from measurements of slope.

Daily gage height, in feet, of Bumping River near Nile, Wash., for 1906.

Day.	June.	July.	Day.	June.	July.	Day.	June.	July.
1		1.05	12		.85	23	1.15	0.5
2		1.05	13	1.5	.8	24	1.1	.5
3		1.05	14	1.4	.75	25	1.1	.5
4		1.2	15	1.35	.75	26	1.1	.5
5		1.15	16	1.4	.7	27	1.1	.45
6		1.2	17	1.35	.65	28	1.05	.45
7		1.1	18	1.3	.65	29	1.05	.45
8		1.05	19	1.25	.6	30	1.05	.4
9		1.0	20	1.2	.6	31		.4
10		.9	21	1.2	.6			
11		.9	22	1.15	.55			

Rating table for Bumping River near Nile, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.40	122	0.70	176	1.00	251	1.30	347
0.50	137	0.80	199	1.10	281	1.40	382
0.60	155	0.90	224	1.20	314	1.50	417

NOTE.—The above table is applicable only for open-channel conditions. It is based on 7 discharge measurements made during 1906 and is well defined.

Monthly discharge of Bumping River near Nile, Wash., for 1906.

[Drainage area 68 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
June 13-30	417	266	318	11,400	4.68	3.13
July	314	122	195	12,000	2.87	3.31
The period				23,400		

NOTE.—Values are rated as excellent.

TIETON RIVER AT HEADWORKS NEAR NACHES, WASH.

This station was established March 29, 1906. It is located 1 mile below the diversion point of the proposed canal of the Tieton project of the Reclamation Service, about 15 miles from the mouth of the river.

The river flows in a narrow canyon cut in basalt. The channel is straight. The right bank is low and brush-covered, and overflows at high water; the left is fairly high and clean. The bed of the stream is of bowlders and gravel, and permanent. There is one channel at all stages. The current is swift and somewhat broken.

Measurements are made from a cable and car.

A vertical 1 by 4 inch gage is drift-bolted to a bowlder at the cable station. The bench mark is a spike in the root of a large pine, 50 feet southeast of the stump to which the cable is attached; elevation, 16.11 feet above the datum of the gage.

Discharge measurements of Tieton River at headworks near Naches, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 12	W. C. Muldrow	75	158	....	416
March 29	J. C. Stevens	94	182	3.47	525
April 17	W. C. Muldrow	95	220	3.90	763
June 2	do	95	195	3.66	644
September 8	do	76	142	3.12	352

Daily gage height, in feet, of Tieton River at Headworks near Naches, Wash., for 1906.

Day.	Apr.	May.	June.	July.	Sept.	Day.	Apr.	May.	June.	July.	Sept.
5		4.25				21	4.4	3.6		3.25	
7		4.2				22	4.6				
12		4.3				23	4.45				
13		4.0				24	4.3			3.3	
14		4.0				25	4.15				
15		4.0				26	4.0				
16		3.9				27	4.0				
17	3.9	3.8			2.86	28	3.95		2.4		
18	3.9	3.65				29	4.2				
19	3.9	3.6				30	4.3				
20	4.1	3.7									

TIETON RIVER NEAR NACHES,[a] WASH.

This station was established April 24, 1902, at a point immediately below the mouth of Oak Creek, in sec. 3, T. 14 N., R. 16 E. of the Willamette meridian, about 3 miles above the mouth of Tieton River and about 22 miles from North Yakima by road. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 89, where are given also references to publications that contain data for previous years. The station was moved upstream March 7, 1906, above the mouth of Oak Creek.

The channel is straight. The banks are high and do not overflow. The bed of the stream is of gravel and solid basalt and changes only during extreme floods. There is one channel at all stages. The current is very swift.

Measurements are made by means of a cable, car, and tagged wire.

The gage, which was read twice a day by Oscar M. Cobb during 1906, is a vertical staff, in two sections: The lower section is bolted to the downstream side of a large bowlder; the upper section is spiked to a tree 20 feet upstream. The bench mark is the highest point of the bowlder to which the gage is attached; elevation, 1,694.65 feet above sea level and 9.25 feet above the datum of the gage.

Discharge measurements of Tieton River near Naches, Wash., in 1906-7.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1906.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 7	W. C. Muldrow	69	147	[b] 6.10	333
March 27	J. C. Stevens	73	160	6.40	474
March 30	do	74	180	6.71	645
May 22	W. C. Muldrow	73	173	6.63	603
June 22	do	72	166	6.41	532
July 14	do	74	187	6.70	657
August 15	do	71	151	6.20	414
November 16 [c]	do	125	728	9.70	5,540
1907.					
February 2	do	65	212	4.80	520

[a] Station formerly referred to as near North Yakima, Wash.
[b] Old gage read 7.20 feet.
[c] Measured by floats.

Daily gage height, in feet, of Tieton River near Naches, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.50	7.30	7.18	6.95	7.65	6.75	6.60	6.15	5.98	5.68	5.80	5.15
2	6.47	7.30	7.18	6.80	7.55	6.78	6.68	6.12	5.92	5.82	5.70	5.10
3	6.60	7.22	7.20	6.78	7.65	7.00	6.85	6.08	5.98	5.90	5.72	5.05
4	6.65	7.15	7.15	6.92	7.70	7.18	6.85	6.12	5.90	5.75	5.88	5.00
5	6.65	7.12	7.10	7.20	7.52	6.90	6.95	6.12	5.90	5.65	5.90	5.00
6	6.62	7.00	7.10	7.42	7.40	6.75	6.95	6.20	6.05	5.68	5.80	5.75
7	6.60	6.98	7.20	7.70	7.35	6.65	6.90	6.18	6.18	5.70	6.00	5.52
8	6.60	7.05	7.30	7.58	7.38	6.58	6.80	6.22	6.05	5.78	6.92	5.52
9	6.60	6.98	6.25	7.45	7.50	6.55	6.70	6.20	5.88	5.70	6.70	5.40
10	6.55	6.95	6.25	7.28	7.62	6.48	6.72	6.22	5.68	5.75	7.55	5.30
11	6.55	6.88	6.05	7.12	7.62	6.62	6.7	6.25	5.58	5.75	7.25	5.28
12	6.55	6.92	6.00	6.98	7.42	6.95	6.68	6.25	5.60	5.75	8.60	5.15
13	6.58	6.90	6.00	6.92	7.20	6.75	6.62	6.25	5.55	5.65	11.80	5.02
14	6.50	6.90	6.02	6.92	7.15	6.58	6.65	6.10	5.68	5.81	13.75	4.92
15	6.50	6.88	6.00	7.02	7.25	6.58	6.58	6.22	5.68	5.78	13.70	5.00
16	6.58	6.85	6.00	7.12	7.00	6.68	6.55	6.10	5.60	6.08	10.00	4.95
17	6.52	6.88	6.00	7.12	6.82	6.65	6.48	6.00	5.72	6.15	7.75	4.95
18	6.48	7.50	5.98	7.10	6.72	6.58	6.38	6.00	5.85	5.92	7.25	4.92
19	6.55	8.60	5.95	7.12	6.68	6.52	6.35	5.92	5.90	5.78	6.90	5.00
20	6.50	8.18	5.95	7.30	6.62	6.48	6.28	5.95	5.90	5.72	6.50	6.15
21	6.50	7.90	5.92	7.62	6.62	6.52	6.30	5.92	5.90	5.68	6.25	7.25
22	6.50	7.75	5.92	7.70	6.60	6.45	6.38	5.90	5.82	5.62	6.05	6.85
23	6.60	7.65	5.95	7.65	6.65	6.40	6.30	5.75	5.85	5.62	5.82	6.55
24	6.80	7.58	6.02	7.45	6.65	6.55	6.22	5.90	5.90	5.62	5.72	6.60
25	6.82	7.45	6.08	7.30	7.18	6.58	6.25	6.05	5.78	6.00	5.62	6.25
26	6.90	7.42	6.22	7.22	7.50	6.75	6.28	6.05	5.65	7.20	5.48	6.10
27	7.05	7.38	6.40	7.20	7.15	6.55	6.20	6.05	5.62	6.72	5.40	5.95
28	6.90	7.30	6.60	7.22	7.00	6.45	6.22	6.05	5.82	6.32	5.32	5.85
29	6.92	....	6.60	7.30	6.88	6.32	6.25	6.08	5.72	6.10	5.30	5.78
30	7.05	....	6.75	7.35	6.82	6.40	6.25	6.12	5.68	5.98	5.20	5.70
31	7.22	....	7.15	....	6.72	....	6.22	6.05	....	5.88	....	5.55

NOTE.—Gage heights prior to March 9 are for a different gage and datum from those after that date. Gage heights from November 12 to 17 were found by plotting several readings a day and taking the mean from the curve.

Rating tables for Tieton River near Naches, Wash.

JANUARY 1, 1905, TO MARCH 8, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
6.30	195	6.80	249	7.30	365	7.80	575	8.30	920
6.40	202	6.90	267	7.40	400	7.90	630	8.40	1,020
6.50	210	7.00	287	7.50	440	8.00	690	8.50	1,130
6.60	220	7.10	310	7.60	480	8.10	755	8.60	1,250
6.70	233	7.20	335	7.70	525	8.20	830		

MARCH 9 TO NOVEMBER 14, 1906.[b]

5.50	155	6.60	593	7.70	1,370	8.80	2,530	10.80	5,720
5.60	182	6.70	649	7.80	1,460	8.90	2,650	11.00	6,120
5.70	212	6.80	708	7.90	1,555	9.00	2,780	11.20	6,560
5.80	244	6.90	770	8.00	1,650	9.20	3,040	11.40	7,000
5.90	278	7.00	835	8.10	1,750	9.40	3,320	11.60	7,440
6.00	315	7.10	905	8.20	1,850	9.60	3,610	11.80	7,920
6.10	355	7.20	975	8.30	1,960	9.80	3,920	12.00	8,400
6.20	398	7.30	1,050	8.40	2,070	10.00	4,240	13.00	11,000
6.30	443	7.40	1,125	8.50	2,180	10.20	4,580	14.00	14,000
6.40	490	7.50	1,205	8.60	2,290	10.40	4,940	15.00	17,700
6.50	540	7.60	1,285	8.70	2,410	10.60	5,320		

[a] This table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904-6, and is well defined between gage heights 6.7 feet and 7.3 feet.

[b] This table is applicable only for open-channel conditions. It is based on 7 discharge measurements made during 1906, and is well defined between gage heights 6 feet and 7 feet. The table has been extended beyond these limits by means of curves of area and mean velocity.

Rating tables for Tieton River near Naches, Wash.—Continued.

NOVEMBER 15 TO DECEMBER 31, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
4.90	530	5.80	1,030	6.70	1,740	7.60	2,665	9.00	4,480
5.00	560	5.90	1,100	6.80	1,830	7.70	2,780	10.00	6,000
5.10	600	6.00	1,170	6.90	1,925	7.80	2,900	11.00	7,750
5.20	645	6.10	1,245	7.00	2,020	7.90	3,020	12.00	9,800
5.30	700	6.20	1,320	7.10	2,120	8.00	3,140	13.00	12,200
5.40	760	6.30	1,400	7.20	2,225	8.20	3,390	14.00	14,950
5.50	825	6.40	1,480	7.30	2,330	8.40	3,650		
5.60	890	6.50	1,565	7.40	2,440	8.60	3,920		
5.70	960	6.60	1,650	7.50	2,550	8.80	4,195		

[a] This table is applicable only for open-channel conditions. It is based on 2 discharge measurements made during 1906-7 and the form of previous curves, and is not well defined.

Monthly discharge of Tieton River near Naches, Wash., for 1906.

[Drainage area, 289 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	341	208	232	14,300	0.803	0.93
February	1,250	258	401	22,300	1.39	1.45
March	940	285	382	23,500	1.32	1.52
April	1,370	696	1,000	59,500	3.46	3.86
May	1,370	593	956	58,800	3.31	3.82
June	961	452	616	36,700	2.13	2.38
July	802	398	500	34,400	1.94	2.24
August	420	228	350	21,500	1.21	1.40
September	389	168	250	14,900	.865	.57
October	975	188	289	17,800	1.00	1.91
November	14,100	212	2,220	132,000	7.68	8.57
December	2,280	536	921	56,600	3.19	3.68
The year	14,100	168	681	492,000	2.36	31.97

NOTE.—Values are rated as follows: January to May, good; June to October, excellent; November and December, fair.

LOW-WATER MEASUREMENTS OF TRIBUTARIES OF LAKE KACHESS.

Small streams discharging into Lake Kachess were measured during the low-water season of 1906 with the following results:

Discharge measurements at low water of tributaries of Kachess Lake, Washington, in 1906.

Date.	Stream.	Discharge.
	East shore:	*Sec.-ft.*
August 22	First creek from outlet	1.0
August 22	Second creek from outlet	2.2
August 22	Third creek from outlet	1.6
August 22	Fourth creek from outlet	2.1
August 22	Fifth creek from outlet	1.0
August 22	Sixth creek from outlet	0.3
August 22	Honolulu Creek	0.5
	West shore:	
August 22	Main Creek	5.8
August 22	Tributary to Main Creek	0.1
August 23	Ninth creek from outlet	0.4
August 23	Eighth creek from outlet	0.1
August 23	Seventh creek from outlet	0.2
August 23	Box Canyon	14
August 23	Gale Creek	0.8
August 23	Fourth creek from outlet	0.5
August 23	Third creek from outlet	0.2
August 23	Second creek from outlet	0.7
August 23	First creek from outlet	1.5

LOW-WATER MEASUREMENTS OF TRIBUTARIES OF LAKE KEECHELUS.

A number of tributaries of Lake Keechelus were measured during the low-water season of 1906, and the results are shown in the following table:

Discharge measurements at low water of tributaries of Keechelus Lake in 1906.

Date.	Stream.	Width.	Area of section.	Discharge.
	East shore:	*Feet.*	*Sq. ft.*	*Sec.-ft.*
August 21[a]	First creek from outlet	3.5	0.8	0.8
August 21[b]	Second creek from outlet			.2
August 21	Trout Creek			1.8
August 21	Fourth creek from outlet	5	1.25	1.8
August 21	Fifth creek from outlet			0.5
August 21	Sixth creek from outlet			6
August 21[b]	Boulder Creek			2.5
August 21[a]	Gold Creek	15	7.5	25
	West shore:			
August 21	Coal Creek	5	2.8	2.5
August 21	Roaring Creek	15	12	36
August 21[c]	Meadow Creek	10	4	3.6

[a] Measured by floats one-half mile above mouth.
[b] Estimated.
[c] Measured by floats 1 mile above mouth.

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous discharge measurements were made in Yakima River drainage basin during 1906:

Atanum Creek.—Measurements were made 2½ miles below Tampico:

April 20 (high water), width, 29 feet; area, 69 square feet; discharge, 207 second-feet.

August 28 (low water), width, 20 feet; area, 11 square feet; discharge, 7.6 second-feet.

A measurement was made at low water August 29 at The Narrows. The water surface was 3.82 feet below a spike in a tree on the right bank near the foot log:

Width, 20 feet; area, 20 square feet; discharge, 20 second-feet.

North Fork of Atanum Creek.—Measurements made at Tampico. The reference point is a nail in a stump on the right bank 2 feet above the second bridge; gage heights are below the reference point:

April 19, width, 30 feet; area, 52 square feet; gage height, −2.00 feet; discharge, 190 second-feet.

August 28, width, 16 feet; area, 11 square feet; gage height, −3.62 feet; discharge, 20 second-feet.

August 29, discharge, 17 second-feet; creek in four channels.

South Fork of Atanum Creek.—Measurements were made 1 mile above Tampico:

April 20 (high water); width, 16 feet; area, 18 square feet; discharge, 54 second-feet.

August 29 (low water); width, 11 feet; area, 10 square feet; discharge, 8.6 second-feet.

Cabin Creek near Easton, Wash.—The discharge of this stream at the wagon bridge on Snoqualmie Road was estimated August 21, at low water, as 7 second-feet.

Clealum River above Lake Clealum.—A measurement was made August 24, 1906, at low water, 2 miles above the head of the lake:

Width, 53 feet; area, 75 square feet; discharge, 189 second-feet.

Cowiche Creek near Cowiche, Wash.—A measurement was made June 3, 1906, just below the head of Cowiche canal:

Width, 18 feet; area, 31 square feet; discharge, 37 second-feet.

South Fork of Cowiche Creek near Cowiche, Wash.—Measurements were made just above the head of the canal:

April 18; width, 19 feet; area, 33 square feet; discharge, 64 second-feet.
September 1; width, 2 feet; area, 0.75 square foot; discharge, 0.71 second-foot.

North Fork of Cowiche Creek.—A measurement was made by floats April 18, 1906, at the corner of sections 20, 21, 28, and 29, T. 14 N., R. 17 E.:

Width, 6 feet; area, 1.8 square feet; discharge, 2.7 second-feet.

Desolation Creek near Roslyn, Wash.—A measurement was made at low water August 24, 1906, one-half mile above mouth:

Width, 4 feet; area, 2 square feet; discharge, 3.4 second-feet.

Oak Creek near Naches, Wash.—This stream is tributary to Tieton River. A measurement was made March 8, 1906, at medium stage:

Width, 7 feet; area, 8.2 square feet; discharge, 13 second-feet.

Silver Creek near Easton, Wash.—A measurement was made by floats at low water, April 23, 1906, at the mouth of canyon:

Width, 7 feet; area, 2.4 square feet; discharge, 3.4 second-feet.

Taneum Creek near Thorp, Wash.—A measurement was made at the highway bridge, 3 miles west of Thorp, March 19, 1906. The water surface was 4.17 feet below a spike in the downstream end of a 12-by-12 inch cap of bent at the left end of the bridge. The stream was at medium stage:

Width, 20 feet; area, 19 square feet; discharge, 22 second-feet.

Yakima River at Easton, Wash.—This station, which was discontinued November 28, 1904, is described in Water-Supply Paper No. 135, page 78. The following measurement was made March 16, 1906:

Width, 146 feet; area, 255 square feet; gage height, 5.30 feet; discharge, 585 second-feet.

Yakima River near Sunnyside, Wash.—A measurement was made at low water August 3, 1906, below Sunnyside dam:

Width, 70 feet; area, 65 square feet; discharge, 45 second-feet.

Yakima River near Richland.—A measurement was made at extreme low water August 17, 1906, 500 feet below the highway bridge.

Water surface 16.15 feet below spike marked "R. P." in downstream end of cap of first pile-pin at right abutment of bridge:

Width, 54 feet; area, 23 square feet; discharge, 29 second-feet.

CANALS IN YAKIMA VALLEY, WASHINGTON.

Descriptions and discharge data of the canals in Yakima Valley are given in Water-Supply Paper No. 178, pages 52–78. Systematic observations of gage heights and discharge were discontinued on most of the canals during 1906.

SUNNYSIDE CANAL NEAR YAKIMA, WASH.

This canal heads on the left bank of Yakima River 5 miles below the town of Yakima. It is owned and operated by the United States Reclamation Service. Measurements are made from a footbridge 200 feet below the head gate. The gage is a vertical staff on the right bank.

Discharge measurements of Sunnyside Canal near Yakima, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 22	W. C. Muldrow	30	17	0.70	14
April 30	do	46	189	4.63	610
June 25	do	45	193	4.80	606
August 3	do	45	166	4.15	484
September 19	do	45	150	3.80	416
September 29	Stevens and Grover	45	153	3.85	410

Daily gage height, in feet, of Sunnyside Canal near Yakima, Wash., for 1906.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	0.6	4.6	4.45	4.9	4.6	3.8	17	3.6	4.7	4.0	5.2	4.55	4.0
2	.6	4.6	4.35	4.9	4.5	3.75	18	3.9	4.7	4.0	5.2	3.8	4.0
3	.6	4.6	4.35	4.9	4.15	3.6	19	3.9	4.7	4.0	5.2	4.2	3.9
4	.6	4.6	4.35	4.9	4.1	3.6	20	4.0	4.7	4.25	5.2	4.2	3.8
5	1.4	4.6	4.35	4.9	4.0	3.6	21	4.2	4.7	4.25	5.2	4.1	3.4
6	1.6	4.6	1.0	4.9	3.85	3.6	22	4.2	4.7	4.55	5.2	3.9	3.8
7	1.9	4.6	3.8	5.0	3.75	3.7	23	4.2	4.7	4.7	5.2	3.9	3.8
8	2.1	4.6	4.05	5.1	4.15	4.0	24	4.35	4.7	4.7	5.2	4.1	3.8
9	2.5	4.7	4.0	5.1	4.1	3.85	25	4.35	4.7	4.8	5.2	3.9	3.8
10	2.8	4.7	4.0	5.1	4.15	4.0	26	4.5	4.6	4.9	5.2	3.9	3.8
11	2.8	4.7	4.0	5.1	4.15	3.85	27	4.5	4.6	4.9	5.2	3.9	3.8
12	2.8	4.7	4.0	5.2	4.5	4.0	28	4.5	4.6	4.9	5.2	3.8	3.8
13	3.0	4.7	4.0	5.2	4.6	4.1	29	4.5	4.6	4.9	5.2	4.0	3.8
14	3.0	4.7	4.0	5.2	4.6	4.1	30	4.63	4.6	4.9	5.2	4.0	3.8
15	3.3	4.7	4.0	5.2	4.5	4.0	31		4.45	......	4.85	3.8	......
16	3.6	4.7	4.0	5.2	4.6	4.0							

Rating table for Sunnyside Canal near Yakima, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.60	12	1.50	75	2.40	180	3.30	317	4.40	529
0.70	16	1.60	85	2.50	194	3.40	334	4.60	572
0.80	20	1.70	95	2.60	208	3.50	352	4.80	616
0.90	26	1.80	106	2.70	222	3.60	370	5.00	660
1.00	33	1.90	117	2.80	237	3.70	389	5.20	704
1.10	41	2.00	129	2.90	252	3.80	408		
1.20	49	2.10	141	3.00	268	3.90	427		
1.30	57	2.20	154	3.10	284	4.00	447		
1.40	66	2.30	167	3.20	300	4.20	487		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905–6 and is fairly well defined.

Monthly discharge of Sunnyside Canal near Yakima, Wash., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
April	579	12	318	18,900
May	594	540	583	35,800
June	638	33	499	29,700
July	704	627	684	42,100
August	572	398	476	29,300
September	467	334	414	24,600
The period				180,000

NOTE.—Values are rated as good.

NEW RESERVATION CANAL NEAR YAKIMA, WASH.

This canal heads on the right bank of Yakima River a short distance below Union Gap gaging station on Yakima River. It is owned and operated by the Indian Department for the irrigation of lands in the Yakima Indian Reservation. Measurements are made at the highway bridge 2,000 feet below head-gate. The gage is a vertical staff attached to the bridge.

Discharge measurements of New Reservation Canal near Yakima, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 22	J. C. Stevens	38	21	[a] 0.60	23
June 29	W. C. Muldrow	40	149	3.55	255
August 3	do	40	149	3.60	145
August 7	do	40	121	3.00	86
September 19	do	40	111	2.60	95
November 5	Muldrow and McGlashan	40	53	1.29	53

[a] Gage height uncertain.

Daily gage height, in feet, New Reservation Canal near Yakima, Wash., for 1906.

Day.	Apr.	May.	June.	Aug.	Sept.	Oct.	Day.	Apr.	May.	June.	Aug.	Sept.	Oct.
1		1.9	2.3		2.6	2.6	17		2.3	2.3	2.8	2.6	2.6
2		2.1	2.3	3.7	2.6	2.6	18		2.3	2.3	3.45	2.6	2.6
3		2.2	2.4	3.6	2.6	2.6	19		2.2	2.3	2.6	2.6	1.3
4		2.2	2.4	3.6	2.6	2.6	20		2.2	.0	2.6	2.6	1.3
5		2.2	2.5	3.6	2.6	2.6	21		2.3	.0	2.6	2.6	1.3
6		2.3	.0	3.6	2.6	2.6	22	4.5	2.3	2.4	2.6	2.6	1.3
7		.0	2.3	2.9	2.6	2.6	23	1.7	2.4	2.7	2.6	2.6	1.3
8		2.4	.0	2.9	2.6	2.6	24	1.6	2.5	2.7	2.6	2.6	1.3
9		2.4	2.2	2.0	2.6	2.6	25	1.6	2.5	2.9	2.6	2.6	1.3
10		2.4	2.2	1.9	2.6	2.6	26	1.8	2.6	3.1	2.6	2.6	1.3
11		2.5	.0	1.9	2.6	2.6	27	1.6	2.5	3.4	2.6	2.6	1.3
12		2.5	2.2	1.9	2.6	2.6	28	1.8	2.3	3.5	2.6	2.6	1.3
13		2.4	2.1	1.9	2.6	2.6	29	1.8	2.3	3.6	2.6	2.6	1.3
14		2.4	2.1	2.8	2.6	2.6	30	1.9	2.3	3.6	2.6	2.6	1.3
15		2.5	2.3	2.8	2.6	2.6	31		2.3		2.6		1.3
16		2.5	2.3	2.8	2.6	2.6							

NOTE.—The growth of certain water plants reduces the velocity of the canal as the season progresses, therefore there is not a constant relation between gage height and discharge.

OLD RESERVATION CANAL NEAR WAPATO, WASH.

This canal takes water from the right bank of Yakima River, 4 miles below Wapato. It is owned and operated by the Indian Department for irrigation of lands in the Yakima Indian Reservation. Measurements are made from railroad bridge one-half mile below head-gate. The gage is a vertical staff at the railroad bridge.

Discharge measurements of Old Reservation Canal near Wapato, Wash., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 22	W. C. Muldrow	11.5	5.6	0.45	4.6
June 29	do	14.0	38	3.10	152
August 3	do	11.8	22	1.75	65
August 7	do	11.3	18	1.40	40
September 19	do	11.3	22	1.85	65
November 5	H. D. McGlashan	12.0	15	1.39	36

Daily gage height, in feet, of Old Reservation Canal near Wapato, Wash., for 1906.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1		3.2	3.1	3.0		1.4	1.3
2			2.0	3.0		1.4	1.3
3			2.0	3.0	1.75	1.4	1.3
4		3.3	2.0	3.0	1.75	1.4	1.3
5			2.0	3.1	1.75	1.4	1.3
6			2.0	3.2	1.5	1.8	1.3
7		3.1	2.0	3.1	1.4	1.8	1.3
8			2.0	3.2	1.45	1.8	1.3
9			2.0	3.1	.8	1.8	1.3
10			2.0	3.0	.8	1.8	1.3
11		3.1	2.0	3.0	.8	1.8	1.3
12			2.0	3.0	.8	1.8	1.3
13			2.0	3.0	.8	1.8	1.3
14		3.2	2.0	3.0	1.7	1.8	1.3
15		3.2	2.0	3.0	1.7	1.8	1.3
16		3.2	2.0	3.0	1.7	1.8	1.3
17		3.15	2.0	3.0	1.7	1.8	1.3
18			2.55	2.9	1.7	1.8	1.3
19		3.2	3.3	2.9	1.7	1.8	1.3
20		3.2	3.3	2.8	1.6	1.8	1.3
21		3.2	3.3	2.8	1.6	1.8	1.3
22		3.2	3.2	2.7	1.55	1.8	1.3
23		3.2	3.2	2.6	1.55	1.8	1.3
24	3.1	3.2	3.1	2.6	1.4	1.8	1.3
25		3.2	3.1	2.55	1.4	1.8	1.3
26	3.22	3.4	3.1	2.5	1.4	1.8	1.3
27		3.4	3.1	2.5	1.4	1.8	1.3
28	3.2	3.5	3.0	2.4	1.4	1.8	1.3
29		3.3	3.0	2.3	1.4	1.3	1.3
30		3.3	3.0	2.2	1.4	1.3	1.3
31		3.1		2.1	1.4		1.3

Rating table for Old Reservation Canal near Wapato, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.50	6	1.20	31	1.90	70	2.60	117	3.30	163
0.60	9	1.30	36	2.00	77	2.70	124	3.40	170
0.70	12	1.40	41	2.10	83	2.80	131	3.50	177
0.80	15	1.50	46	2.20	89	2.90	138		
0.90	18	1.60	52	2.30	96	3.00	145		
1.00	22	1.70	58	2.40	103	3.10	152		
1.10	26	1.80	64	2.50	110	3.20	159		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 6 discharge measurements made during 1906 and is well defined.

Monthly discharge of Old Reservation Canal near Wapato, Wash., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
May	177	152	159	9,780
June	163	77	112	6,660
July	159	83	133	8,180
August	75	15	45.5	2,800
September	64	36	58.3	3,470
October	36	36	36.0	2,210
The period				33,100

NOTE.—Values are rated as good.

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made on canals in Yakima Valley, Washington, in 1906.

Miscellaneous measurements of canals in Yakima River drainage basin, Washington, in 1906.

Date.	Canal.	Locality.	Width.	Area of section.	Gage height.	Discharge.
			Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
August 6	Bull	Head-gate, Ellensburg	6	8.8	1.78	20
March 19	Cascade	Upper flume, Thorp	8	6.4	0.80	22
April 18	Cowiche	2 miles above Cowiche	7	6.3	....	11
June 3	do	Head-gate, Cowiche	5	5.5	....	12
September 1	do	do	2	0.48	....	0.26
April 20	Farmers ditch	Highway crossing, Tampico	3.5	2.4	....	4.1
April 15	Fortune	Foster's ranch	5.7	2.3	0.45	1.4
April 7	Fowler	North Yakima	9.7	5.3	....	6.5
April 22	do	do	9.7	9.7	0.70	27
April 22	Granger	do	3.5	0.52	....	0.45
August 4[a]	Hatch	Toppenish	6	4.2	....	4
April 7	Hubbard	North Yakima	13.1	17	1.30	12
April 22	do	do	15	25	1.75	31
April 22	Moxee	do	10	12	2.03	14
August 16	Old Union	North Yakima:				
		2,000 feet below head-gate	14	36	2.82	42
		At head-gate	12.2	20	1.44	29
		do	12.2	18	1.40	27
		do	11.5	16	1.21	17
		do	12.7	23	1.75	40
		2,000 feet below head-gate			2.65	29
August 6	Olsen	Ellensburg	11	25	2.50	40
May 17	Prosser	Prosser	6.5	12	2.12	18
May 23	Selah Valley	Natchez:				
		Wastegate No. 12	6.8	14	....	56
		Above control gates	8.5	26	....	78
		Below control gates	8.8	26	2.75	75
		At flume No. 8	8.0	20	....	67
		At flume No. 23	6.8	17	....	62
		At head-gate	18.5	42	3.58	93
April 20	Shaw ditch	1½ miles above Atanum	14	10	....	6.0
April 20	Stair ditch	2 miles above Atanum	4.5	2.5	....	4.7
March 19[b]	Taneum	Thorp	10.5	5.9	0.57	11
May 5	Town	Ellensburg	14	38	2.68	115
August 6	do	do	14	40	2.85	125
April 3	do	North Yakima	5.7	6	1.00	7.5
April 3	do	do	5.7	6.2	1.08	8.3
April 3	do	do	5.7	9.5	1.71	20
April 15	do	do	5.7	7.5	1.26	11
March 1	Union	do	11.5	11	0.98	9
August 16	do	Naches avenue, North Yakima	6	13	2.52	33
April 26	Union Gap	North Yakima	3.8	1.7	0.45	1.5
August 9[c]	Wapaton	do	2.0	54	....	117
April 5	Yakima Valley (Congdon).	Head	8.5	8.6	0.48	12

[a] Measured by floats.

[b] Water probably raised by ice gorge below.

[c] Three-fourths mile below head-gate.

SNAKE RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Snake River, the largest tributary of the Columbia, rises among the high peaks of the Rocky Mountains in Yellowstone National Park, western Montana and eastern Wyoming, heading in the divide from which streams flow northward and eastward into the Missouri and southward and westward to the Colorado and the lakes of the Great Basin. From Shoshone, Lewis, and Hart lakes, in Yellowstone National Park, the south fork of the river flows southward, broadening into Jackson Lake (4 miles wide and 18 miles long) and passing through Jackson Valley (8 miles wide and 40 miles long), beyond which, near the Idaho-Wyoming line, it enters a long canyon. In the southern part of Fremont County, Idaho, it unites with North Fork. Below the junction of the forks it flows westward across Idaho to a point near Homedale, where it turns abruptly northward, forming for about 170 miles the boundary between Idaho and Oregon and for 30 miles more that between Idaho and Washington. At Lewiston it crosses into Washington, flows northwest, west, and southwest, and joins the Columbia at Pasco Junction.

Its upper drainage basin comprises the timbered mountainous country west and southwest of Yellowstone Lake. The east side of its valley is bounded by the Wind River Range, from the slopes of which it receives a number of tributaries, and the west side by the high Teton Mountains, from which most of the drainage flows westward through Teton River into North Fork.

Below the junction of North and South forks the Snake receives many important tributaries, among which may be mentioned Boise, Salmon, Clearwater, and Palouse rivers from the north and east and Owyhee, Malheur, Powder, and Grande Ronde rivers from the south and west.

The Owyhee, which joins the Snake at Owyhee, Oreg., drains a high, broken, timberless area, in portions of which the rainfall amounts to but 8 or 10 inches per annum. In many respects the drainage area of the Malheur is similar to that of the Owyhee, but parts of the headwater region are mountainous and rather heavily timbered. The drainage basin of the Grande Ronde, comprising the eastern slope of the Blue Mountains and the western slope of the Cornucopia Range in northeastern Oregon, is throughout mountainous and heavily timbered, and for much of its course the river occupies a deep canyon. Wallowa River, its principal tributary, closely resembles it. Grande Ronde Valley, a broadening of the Grande Ronde basin at the town of La Grande, and Wallowa Valley, a similar broadening of Wallowa River below the town of Joseph, are important agricultural areas within the Grande Ronde drainage basin. Powder and Palouse rivers and Asotin Creek drain areas similar in character, utilized chiefly for dry farming and the production of wheat. The waters of all of these streams are valuable for irrigation, which in a number of the valleys—notably that of the Malheur—has reached a comparatively high stage of development. At Asotin a power plant is operated, and the waters used for power are also used for irrigation.

NORTH FORK OF SNAKE RIVER NEAR ORA, IDAHO.

This station was established August 20, 1902. It is located at the North Fork Bridge, 2 miles south of Ora and 10 miles above St. Anthony, Idaho. The bench mark is a United States Geological Survey aluminum tablet set in a large rock about 30 feet northeast from the north end of the bridge; elevation, 12.84 feet above the gage datum.

The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 91, where are given also references to publications that contain data for previous years.

Discharge measurements of North Fork of Snake River near Ora, Idaho, in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 11	E. C. La Rue	178	505	2.90	2,170
May 27	do	178	470	2.70	1,900
June 17	do	178	496	2.85	2,130

Daily gage height, in feet, of North Fork of Snake River near Ora, Idaho, for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	2.0	2.0	2.0	1.9	3.3	2.9	2.5	2.1	2.1	2.0	2.1
2	2.0	2.0	2.0	1.9	3.3	2.9	2.5	2.1	2.1	2.0	2.1
3	2.0	2.0	2.0	1.9	3.3	2.8	2.5	2.1	2.1	2.0	2.1
4	2.0	1.9	2.0	1.9	3.3	2.9	2.4	2.1	2.0	2.0	2.1
5	2.0	1.9	1.9	1.9	3.1	3.0	2.4	2.1	2.0	2.0	2.1
6	2.0	1.9	1.9	1.9	3.1	3.2	2.4	2.1	2.0	2.0	2.1
7	2.0	1.9	1.9	1.9	2.9	3.2	2.4	2.1	2.0	2.0	2.1
8	2.0	2.0	1.9	2.0	2.9	3.1	2.4	2.1	2.0	2.1	2.1
9	2.0	2.0	1.9	2.0	2.9	3.0	2.4	2.1	2.1	2.1	2.1
10	2.0	2.0	1.9	2.0	2.8	2.9	2.4	2.0	2.1	2.1	2.1
11	2.0	2.0	1.9	2.1	2.8	2.9	2.4	2.0	2.1	2.1	2.1
12	2.0	2.0	1.9	2.1	2.8	2.8	2.3	2.0	2.1	2.1	2.1
13	2.0	2.0	1.9	2.1	2.8	2.8	2.3	2.0	2.1	2.1	2.1
14	2.0	2.0	1.9	2.1	2.9	2.8	2.3	2.0	2.2	2.1	2.1
15	2.0	2.0	1.9	2.1	2.9	2.8	2.3	2.0	2.2	2.1	2.1
16	2.0	2.0	1.9	2.1	2.9	2.7	2.3	2.0	2.2	2.1	2.1
17	2.0	2.0	1.9	2.2	2.8	2.8	2.3	2.0	2.2	2.1	2.1
18	2.0	2.0	1.9	2.2	2.8	2.8	2.3	2.1	2.2	2.1	2.0
19	2.0	2.0	1.9	2.2	2.7	2.7	2.3	2.1	2.1	2.1	2.0
20	2.0	2.0	1.9	2.2	2.7	2.7	2.3	2.1	2.1	2.1	2.0
21	2.0	2.0	2.0	2.2	2.7	2.6	2.3	2.1	2.1	2.1	2.0
22	2.0	2.0	2.0	2.5	2.6	2.6	2.2	2.2	2.1	2.1	2.0
23	2.0	2.0	2.0	2.5	2.6	2.6	2.2	2.2	2.1	2.1	2.0
24	2.0	2.0	2.0	2.8	2.6	2.6	2.2	2.2	2.1	2.1	2.0
25	2.0	2.0	2.0	3.0	2.7	2.5	2.2	2.2	2.1	2.1	2.0
26	2.0	2.0	2.0	3.0	2.7	2.5	2.2	2.2	2.1	2.1	2.0
27	2.0	2.0	2.0	3.1	2.7	2.5	2.2	2.2	2.1	2.1	2.0
28	2.0	2.0	1.9	3.2	2.7	2.5	2.2	2.1	2.1	2.1	2.0
29	2.0	....	1.9	3.3	2.9	2.5	2.2	2.1	2.1	2.1	2.0
30	2.0	....	1.9	3.3	3.1	2.5	2.1	2.1	2.2	2.1	2.0
31	2.0	....	1.9	....	3.0	....	2.1	2.1	....	2.1	([a])

[a] Record discontinued for the winter.

Rating table for North Fork of Snake River near Ora, Idaho, for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.90	910	2.20	1,170	2.50	1,550	2.80	2,030	3.10	2,600
2.00	990	2.30	1,280	2.60	1,700	2.90	2,210	3.20	2,810
2.10	1,070	2.40	1,410	2.70	1,860	3.00	2,400	3.30	3,030

NOTE.—The above table is applicable only for open-channel conditions. It is based on 8 discharge measurements made during 1905–6 and is well defined.

Monthly discharge of North Fork of Snake River near Ora, Idaho, for 1906.

[Drainage area, 1,040 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	990	990	990	60,900	0.952	1.10
February	990	910	979	54,400	.942	.98
March	990	910	938	57,700	.902	1.04
April	3,030	910	1,430	85,300	1.38	1.54
May	3,030	1,700	2,200	135,000	2.11	2.43
June	2,810	1,550	2,000	119,000	1.92	2.14
July	1,550	1,070	1,300	79,800	1.25	1.44
August	1,170	990	1,070	65,700	1.03	1.19
September	1,170	990	1,080	64,100	1.04	1.16
October	1,070	990	1,050	64,700	1.01	1.16
November	1,070	990	1,030	61,600	.995	1.11
The period				848,000		

NOTE.—Values are rated as excellent on the assumption that the flow was not affected by ice conditions, January to March.

SNAKE RIVER NEAR MINIDOKA, IDAHO.

This station was originally established August 5, 1895, at Montgomery's ferry, on the stage road from Minidoka to Albion, 4 miles east of Rupert, Idaho, and 10 miles below the diversion dam for the Minidoka irrigation project. Measurements at Montgomery's ferry show the amount of water available for irrigation purposes there and for the newly constructed Twin Falls canals heading 23 miles below, and also the conditions that will exist for power purposes at Shoshone Falls, about 45 miles below, after the irrigable lands of Snake River Valley shall have been reclaimed. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 93, where are given also references to publications that contain data for previous years.

Discharge measurements of Snake River near Minidoka, Idaho, in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 12	E. C. La Rue	815	4,020	3.15	6,120
April 26	do	835	4,980	4.34	9,590
May 19	do	860	6,610	6.29	16,100
June 9	do	865	7,970	7.92	22,500

Daily gage height, in feet, of Snake River near Minidoka, Idaho, in 1906.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	....	2.7	3.4	4.7	7.35	4.4	2.4	2.2	2.65
2	(a)	2.7	3.4	4.7	7.5	4.4	2.25	2.3	2.65
3	3.25	3.0	3.3	4.8	7.7	4.4	2.2	2.35	2.6
4	3.2	2.9	3.15	4.95	7.8	4.4	2.05	2.35	2.7
5	3.2	2.7	3.15	5.1	7.8	4.4	1.9	2.35	2.65
6	3.0	2.7	3.2	5.5	7.85	4.4	1.8	2.35	2.6
7	3.0	2.7	3.1	5.5	7.8	4.4	1.7	.6	2.6
8	2.9	2.7	3.1	5.6	7.85	4.4	1.6	.75	2.6
9	3.05	2.7	3.0	5.55	7.85	4.4	1.6	1.9	2.55
10	3.3	2.7	3.0	5.5	8.0	3.85	1.55	2.1	2.4
11	3.05	2.7	3.0	5.4	8.0	3.35	1.5	2.1	2.35
12	2.7	2.7	3.1	5.4	7.95	3.3	1.5	2.1	2.35
13	2.4	2.65	3.25	5.5	7.85	3.3	1.45	2.1	2.4
14	2.2	2.6	3.25	5.55	7.7	3.2	1.45	2.1	2.4
15	2.35	2.5	3.25	5.75	7.9	3.2	1.45	2.1	2.4
16	2.5	2.35	3.3	5.9	8.0	3.2	1.45	2.1	2.6
17	2.6	2.45	3.2	6.1	8.15	3.4	1.45	2.1	2.95
18	2.6	2.9	3.2	6.25	8.2	4.8	1.45	2.15	2.9
19	2.6	2.8	3.2	6.3	8.3	5.2	1.45	2.2	3.2
20	2.65	2.55	3.25	6.3	8.3	5.1	1.45	2.2	3.4
21	2.7	2.4	3.45	6.25	8.1	5.1	1.45	2.25	3.6
22	2.7	2.35	3.6	6.2	7.8	5.0	1.5	2.25	3.5
23	2.7	2.5	3.7	6.15	7.5	4.75	1.5	2.25	3.35
24	2.75	2.6	4.0	6.2	7.25	4.6	1.5	2.3	3.25
25	2.75	2.8	4.2	6.2	6.85	4.4	1.5	2.4	3.2
26	2.75	3.05	4.3	6.2	6.6	4.15	2.1	2.7	3.2
27	2.7	3.2	4.45	6.2	6.35	4.9	2.45	2.7	3.15
28	2.7	3.3	4.65	6.45	6.05	3.7	2.6	2.7	3.1
29	....	3.3	4.7	6.55	5.4	3.45	2.55	2.7	3.05
30	....	3.4	4.7	6.8	4.75	3.1	2.2	2.65	3.0
31	....	3.4	....	7.05	....	2.7	2.2	....	(b)

[a] River frozen over January 1 to February 2, 1906.

[b] Gates at Minidoka dam were closed during November. Records at gaging station were unreliable November 1 to December 31.

Rating table for Snake River near Minidoka, Idaho, for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.60	1,640	1.70	2,670	2.70	4,930	3.70	7,630	5.40	12,950
.70	1,680	1.80	2,860	2.80	5,180	3.80	7,920	5.60	13,670
.80	1,720	1.90	3,060	2.90	5,440	3.90	8,210	5.80	14,390
.90	1,760	2.00	3,270	3.00	5,700	4.00	8,500	6.00	15,110
1.00	1,820	2.10	3,480	3.10	5,970	4.20	9,080	6.20	15,830
1.10	1,880	2.20	3,700	3.20	6,240	4.40	9,680	6.40	16,550
1.20	1,960	2.30	3,940	3.30	6,510	4.60	10,280	6.60	17,270
1.30	2,060	2.40	4,180	3.40	6,780	4.80	10,890	6.80	18,010
1.40	2,190	2.50	4,430	3.50	7,060	5.00	11,540	7.00	18,790
1.50	2,340	2.60	4,680	3.60	7,340	5.20	12,230	8.00	23,010
1.60	2,500								

NOTE.—The above table is applicable only for open-channel conditions. It is based on 11 discharge measurements made during 1905-6 and is well defined above 2.3 feet; below that it is uncertain.

Monthly discharge of Snake River near Minidoka, Idaho, for 1906.

[Drainage area, 17,900[a] square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec. ft. per sq. mile.	Depth in inches.
February (3-28)	6,510	3,700	5,150	265,000	0.288	0.28
March	6,780	4,060	5,130	316,000	.287	.33
April	10,600	5,700	7,150	425,000	.399	.44
May	19,000	10,600	14,500	892,000	.810	.93
June	24,300	10,700	20,900	1,250,000	1.17	1.30
July	12,200	4,930	8,870	546,000	.496	.57
August	4,680	2,260	2,900	178,000	.162	.19
September	4,930	1,640	3,770	225,000	.211	.23
October	7,340	4,060	5,320	317,000	.297	.33
The period	....	....	....	4,410,000	....	....

[a] Exclusive of drainage of Big and Little Lost rivers.

NOTE.—Values are rated as follows: February to July, and October, excellent; August and September, good.

SNAKE RIVER BETWEEN MILNER DAM AND SHOSHONE FALLS, DURING NOVEMBER, 1906.

The following is a brief report of investigations in regard to the source and volume of flow in Snake River between the Milner dam, Milner, Idaho, and Shoshone Falls, Idaho, dating from November 14 to 22 (inclusive), 1906, when the flow was entirely cut off at the Minidoka dam.

The flow at this time below the Milner dam was derived from leakage through the gates at the dam, waste water from the Twin Falls tract, and springs along its course. In no case did water flow over the Milner dam and the waste from the Twin Falls tract was at a minimum

In passing down the river from Milner to Shoshone Falls, discharge measurements were made as often as suitable stations could be found. All springs of appreciable size entering between Milner and Shoshone Falls lie between Shoshone Falls and a point 6 miles above. Most of them enter on the north side. The source of these springs is not definitely known. Upon them will depend the permanent flow of Snake River over Shoshone Falls at future times if all the water is diverted above for irrigation, with no waste.

The following is a tabulation of the measurements taken:

Measurements between Milner Dam and Shoshone Falls in 1906.

Date.	Location.		Discharge.	Date.	Location.		Discharge.
	Above Shoshone Falls.	Below Milner.			Above Shoshone Falls.	Below Milner.	
	Feet.	*Miles.*	*Sec.-ft.*		*Feet.*	*Miles.*	*Sec.-ft.*
November 14	1,500		195	November 18		6	20
November 15	1,500		165	November 18		7	27
November 16	1,500		158	November 20		16	60
November 17		2	22	November 21	1,500		169
November 18		4	17	November 22	1,500		200

During the investigation the minimum flow measured at Shoshone Falls was 158 second-feet. The measurements made between the Milner dam and a point 7 miles below show that about 30 second-feet come from leakage through the Milner dam and waste from the Twin Falls tract; there then remains 128 second-feet as the gain in discharge between Milner dam and Shoshone Falls. Just what part of this is spring water and what part drains from pools can not be determined. Throughout the course there are a great many pools from 200 feet to 1 mile in length. No doubt it would take considerable time for these pools to drain down to a normal stage.

There is but one conclusion to be drawn and that is that the permanent flow over Shoshone Falls during the irrigation season, when the water is all diverted above, will be reduced to approximately 130 second-feet or less.

SNAKE RIVER AT NEELEY, IDAHO.

On March 17, 1906, a temporary station was established at Neeley, Idaho, 3 miles above the backwater from the Minidoka dam and 4 miles below American Falls. This station is to eventually take the place of the old Montgomery station below the Minidoka dam. During 1906 only gage readings were taken. The station will be rated at some future time.

Daily gage height, in feet, of Snake River at Neeley, Idaho, for 1906.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	5.3	6.8	9.8	6.65	....	4.9	....	4.9	5.0
2	....	5.25	7.0	9.7	6.5	4.2	4.8	....	4.9	5.0
3	....	5.25	7.5	9.65	6.4	....	4.65	....	4.9	5.0
4	....	5.2	7.1	9.4	6.5	4.0	4.5	4.6	5.0	5.0
5	....	5.15	7.15	9.4	6.65	4.0	4.5	4.6	5.0	5.0
6	....	5.15	7.35	9.3	6.7	3.9	4.6	4.6	5.0	(a)
7	....	5.1	7.6	9.5	6.6	3.8	6.5	4.7	5.0	....
8	....	5.05	7.4	9.7	6.5	3.8	6.3	4.7	5.0	....
9	....	5.05	7.25	9.75	6.4	3.75	5.0	4.7	5.0	....
10	....	5.1	7.15	9.5	6.4	3.7	4.3	4.7	5.0	....
11	....	5.25	7.1	9.3	6.3	3.7	4.3	4.7	5.0	....
12	....	5.4	7.4	9.0	6.3	3.7	4.35	4.7	5.0	....
13	....	5.35	7.65	9.1	6.3	3.7	4.4	4.7	5.0	....
14	....	5.3	7.85	9.5	6.3	3.7	4.5	4.7	5.0	....
15	....	5.15	8.2	9.7	6.3	3.7	4.5	4.8	5.0	....
16	....	5.1	8.5	10.0	6.3	3.7	4.5	4.8	5.0	....
17	4.55	5.2	8.6	9.85	6.2	3.7	4.6	4.8	5.0	....
18	4.55	5.3	8.7	9.75	6.1	3.7	4.7	4.8	5.0	....
19	4.55	5.4	8.3	9.65	6.0	3.7	4.75	4.8	5.0	....
20	4.6	5.45	8.0	9.5	6.0	3.65	4.8	4.8	5.0	....
21	4.65	5.8	7.6	8.9	5.9	3.65	4.8	4.8	5.0	....
22	4.7	5.95	7.75	8.0	5.8	3.65	4.8	4.8	5.0	....
23	4.7	6.05	7.9	7.7	5.7	3.7	4.7	4.9	5.0	....
24	4.95	6.35	7.8	7.5	5.6	3.8	4.7	4.9	5.0	....
25	5.2	6.7	7.95	7.3	5.5	4.1	4.7	4.9	5.0	....
26	5.35	6.9	8.1	7.0	5.4	4.6	4.7	4.9	5.0	....
27	5.6	6.85	8.65	6.7	5.2	4.95	4.7	4.9	5.0	....
28	5.45	6.8	9.2	6.6	....	4.95	4.6	4.9	5.0	....
29	5.35	6.75	9.4	6.5	....	4.95	4.6	4.9	5.0	....
30	5.35	6.65	9.5	6.7	....	4.95	4.6	4.9	5.0	....
31	5.45	....	9.9	....	....	4.9	....	4.9	....	....

[a] Record discontinued for the winter.

FALL RIVER AT FREMONT, IDAHO.

This station was established January 1, 1904, about 900 feet from Fremont post-office. During 1906 the gage was read once each day by Mrs. Eva A. Loomis and C. R. Scheetz. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 97, where are given also references to publications that contain data for previous years.

Discharge measurements of Fall River at Fremont, Idaho, in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 11	E. C. La Rue	147	362	3.25	1,640
May 27	do	148	369	3.32	1,690
June 17	do	149	448	3.85	2,510
August 17	do	140	184	2.02	468

Daily gage height, in feet, of Fall River at Fremont, Idaho, for 1906.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1		2.8	3.5	3.1	1.9	1.9	1.9	1.9
2		2.1	3.6	3.2	2.0	1.9	1.9	1.9
3		2.1	3.55	3.0	2.05	1.9	1.95	1.9
4		2.1	3.4	3.0	2.05	1.9	1.95	1.9
5		2.9	3.85	3.1	2.0	1.95	1.95	1.9
6	(a)	2.1	3.95	3.3	2.0	1.8	1.95	1.9
7	1.9	2.1	3.8	3.1	2.0	1.9	1.9	1.9
8	1.9	2.1	3.65	3.0	2.0	1.9	1.9	1.9
9	1.9	3.0	3.3	3.0	2.0	1.9	1.9	1.9
10	1.9	3.0	3.0	3.1	2.0	1.9	1.9	1.9
11	1.9	3.1	3.4	3.1	2.0	1.9	1.9	1.9
12	1.9	3.2	3.3	3.0	2.0	1.9	1.9	1.9
13	1.9	3.1	3.55	2.9	2.0	1.9	1.95	1.9
14	1.9	3.3	3.65	2.8	2.05	1.95	1.95	1.9
15	1.9	3.8	3.5	2.6	2.05	2.05	1.95	1.9
16	1.9	3.4	3.3	2.6	2.0	1.95	1.95	1.9
17	2.0	2.9	3.95	2.6	2.0	1.9	1.95	1.9
18	2.05	2.85	3.55	2.5	2.0	1.9	1.95	(b)
19	2.1	2.95	3.3	2.3	2.05	1.9	1.95	....
20	2.1	2.1	3.1	2.3	2.05	1.9	1.95	....
21	2.15	2.1	3.0	2.5	2.0	1.9	1.9	....
22	2.25	3.0	3.0	2.4	2.0	1.9	1.9	....
23	2.45	3.1	3.0	2.3	2.1	1.95	1.9	....
24	2.65	3.4	3.0	2.2	2.15	1.9	1.9	....
25	2.6	3.65	3.0	2.3	2.05	1.9	1.9	....
26	2.5	3.5	2.9	2.3	2.0	1.9	1.9	....
27	2.5	3.5	3.1	2.2	2.05	1.9	1.9	....
28	2.55	3.55	3.25	2.0	2.0	1.9	1.9	....
29	2.7	3.6	3.0	1.9	1.9	1.9	1.9	....
30	2.8	3.45	3.3	1.9	1.9	1.9	1.9	....
31	....	3.5	....	2.0	1.9	....	1.9	....

[a] No record on account of ice January 1 to April 6, 1906.
[b] Record discontinued for the winter on November 18.

Rating table for Fall River at Fremont, Idaho, for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.40	168	2.00	485	2.60	945	3.20	1,565	3.80	2,345
1.50	210	2.10	555	2.70	1,035	3.30	1,685	3.90	2,495
1.60	255	2.20	625	2.80	1,125	3.40	1,815	4.00	2,655
1.70	305	2.30	700	2.90	1,225	3.50	1,945		
1.80	365	2.40	775	3.00	1,335	3.60	2,075		
1.90	425	2.50	860	3.10	1,445	3.70	2,205		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 8 discharge measurements made during 1905-6 and is well defined.

Monthly discharge of Fall River at Fremont, Idaho, for 1906.

[Drainage area, 390 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
April 7-30	1,120	425	631	30,000	1.62	1.45
May	2,340	555	1,350	83,200	3.47	4.00
June	2,580	1,220	1,780	105,800	4.56	5.09
July	1,680	425	1,010	62,300	2.60	3.00
August	590	425	492	30,200	1.26	1.45
September	520	365	430	25,600	1.10	1.23
October	455	425	437	26,900	1.12	1.29
November 1-17	425	425	425	14,300	1.09	.69
The period				378,000		

NOTE.—Values are rated as follows: May to July, excellent; April and August to November, good.

TETON RIVER NEAR ST. ANTHONY, IDAHO.

This station was established April 23, 1903. It is located at the bridge on the stage road from St. Anthony to Victor, Idaho. The bench mark is a United States Geological Survey aluminum tablet set in solid rock about 30 feet northeast of the north end of the bridge; elevation, 13.53 feet above the gage datum. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 99, where are given also references to publications that contain data for previous years.

Discharge measurements of Teton River near St. Anthony, Idaho, in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 12	E. C. La Rue	79.5	438	3.20	1,640
May 28	do	79.5	477	3.65	2,100
June 18	do	79.5	498	3.90	2,270
August 13	do	79.5	350	1.95	646

Daily gage height, in feet, of Teton River near St. Anthony, Idaho, for 1906.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		1.3	1.6	2.0	3.65	2.65	2.05	1.8	1.75	1.7	1.6
2		1.35	1.5	2.1	3.55	2.8	2.05	1.75	1.75	1.7	1.6
3		1.35	1.6	2.15	3.5	2.95	2.05	1.75	1.85	1.7	1.7
4		1.3	1.6	2.3	3.9	3.0	2.05	1.75	1.85	1.7	1.8
5		1.35	1.65	2.4	3.1	3.0	2.1	1.8	1.8	1.7	1.8
6		1.35	1.7	2.3	4.25	2.95	2.05	1.8	1.8	1.75	1.7
7		1.3	1.9	2.25	4.1	2.95	2.05	1.8	1.75	1.75	1.65
8		1.3	2.0	2.3	3.8	2.85	2.05	1.8	1.75	1.65	1.6
9		1.3	2.1	2.5	3.5	2.95	2.05	1.8	1.7	1.65	[a]
10		1.3	2.15	2.85	3.45	2.85	2.0	1.8	1.7	1.65	
11		1.1	2.2	3.0	3.9	2.8	2.0	1.8	1.7	1.65	
12		1.0	2.15	3.3	4.25	2.75	1.9	1.8	1.7	1.65	
13		1.2	2.1	3.4	4.9	2.75	1.9	1.8	1.7	1.65	
14		1.3	2.0	3.6	4.95	2.7	1.85	1.85	1.75	1.65	
15		1.4	2.1	3.85	4.35	2.65	1.85	1.95	1.75	1.6	
16		1.2	2.25	3.7	4.2	2.6	1.85	2.0	1.7	1.6	
17		1.2	2.45	3.2	4.15	2.6	1.85	2.0	1.75	1.6	
18		1.1	2.35	2.85	3.9	2.6	1.8	1.9	1.75	1.6	
19	1.3	1.1	2.15	2.6	3.45	2.55	1.85	1.9	1.75	1.65	
20	1.3	1.1	2.1	2.8	3.0	2.5	1.9	1.8	1.75	1.7	
21	1.25	1.1	2.0	3.0	2.9	2.35	1.95	1.8	1.75	1.65	
22	1.3	1.2	2.1	3.1	2.95	2.4	1.9	1.8	1.7	1.6	
23	1.3	1.25	2.2	2.95	2.9	2.4	1.95	1.8	1.7	1.65	
24	1.3	1.3	2.3	3.15	2.8	2.4	2.0	1.8	1.7	1.65	
25	1.3	1.3	2.35	4.1	2.65	2.3	2.0	1.8	1.7	1.6	
26	1.3	1.35	2.15	4.5	2.7	2.25	2.0	1.8	1.7	1.6	
27	1.35	1.35	2.0	3.95	2.7	2.2	1.95	1.75	1.7	1.6	
28	1.35	1.4	1.9	3.6	2.75	2.1	1.9	1.75	1.7	1.6	
29		1.5	1.9	3.95	2.9	2.1	1.9	1.75	1.7	1.6	
30		1.6	1.95	3.1	2.65	2.1	1.85	1.75	1.7	1.6	
31		1.65		3.8		2.1	1.8		1.7		

[a] Discontinued for the winter.

Rating table for Teton River near St. Anthony, Idaho, for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.00	88	1.80	548	2.60	1,100	3.40	1,755	4.40	3,045
1.10	142	1.90	610	2.70	1,177	3.50	1,850	4.60	3,385
1.20	197	2.00	674	2.80	1,255	3.60	1,950	4.80	3,740
1.30	253	2.10	740	2.90	1,335	3.70	2,060	5.00	4,115
1.40	310	2.20	808	3.00	1,417	3.80	2,175		
1.50	368	2.30	878	3.10	1,500	3.90	2,300		
1.60	427	2.40	950	3.20	1,584	4.00	2,435		
1.70	487	2.50	1,024	3.30	1,669	4.20	2,730		

NOTE.—The above table is strictly applicable only for open-channel conditions. It is based on 14 discharge measurements made during 1904–1906 and is well defined above gage height 1.5 feet.

Monthly discharge of Teton River near St. Anthony, Idaho, for 1906.

[Drainage area, 960 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
February 19–28	281	225	256	5,080	0.267	0.10
March	457	88	247	15,200	.257	.30
April	987	368	690	41,100	.719	.80
May	3,220	674	1,520	93,700	1.59	1.83
June	4,020	1,140	2,010	119,000	2.09	2.33
July	1,420	740	1,100	67,400	1.14	1.31
August	740	548	643	39,500	.670	.77
September	674	517	557	33,100	.580	.65
October	579	487	508	31,200	.529	.61
November	517	427	456	27,100	.475	.53
December 1–8	548	427	476	7,550	.496	.15
The period				480,000		

NOTE.—Values are rated as follows: February and March, good; April to December, excellent.

SOUTH FORK OF SNAKE RIVER AT MORAN, WYO.

This station was established September 21, 1903. It is located directly back of the post-office at Moran, Wyo., and about three-fourths mile below the outlet of Jackson Lake. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 101, where are given also references to publications that contain data for previous years.

Discharge measurements of South Fork of Snake River at Moran, Wyo., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
June 19	R. J. Newell	202	1,190	5.52	5,740
June 24	do	202	1,030	4.70	4,290
August 25	E. C. La Rue	198	520	1.85	962

Daily gage height, in feet, of South Fork of Snake River at Moran, Wyo., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	1.0	1.2	1.25	1.2	1.7	4.7	4.4	2.7	1.7	1.25
2	1.0	1.2	1.25	1.2	1.75	4.7	4.3	2.65	1.7	1.25
3	1.0	1.2	1.2	1.2	1.8	4.7	4.3	2.6	1.65	1.25
4	1.0	1.15	1.2	1.2	1.85	4.6	4.25	2.5	1.65	1.25
5	1.0	1.15	1.2	1.2	1.9	4.4	4.25	2.5	1.65	1.2
6	1.0	1.15	1.2	1.2	1.95	4.6	4.25	2.45	1.65	1.2
7	1.0	1.1	1.2	1.2	2.0	4.8	4.25	2.4	1.65	1.2
8	1.0	1.1	1.2	1.2	2.05	4.75	4.25	2.35	1.65	1.2
9	.9	1.1	1.2	1.2	2.15	4.7	4.25	2.15	1.6	1.15
10	.9	1.1	1.2	1.2	2.25	4.8	4.25	1.95	1.6	1.15
11	.9	1.15	1.2	1.2	2.35	4.85	4.2	1.95	1.55	1.1
12	.9	1.15	1.2	1.2	2.55	4.9	4.2	1.9	1.55	1.1
13	.9	1.15	1.2	1.2	2.8	5.0	3.95	1.9	1.5	(a)
14	.9	1.15	1.2	1.2	3.15	5.1	3.95	1.95	1.5	....
15	.9	1.15	1.2	1.2	3.45	5.25	3.8	1.95	1.45	....
16	.9	1.15	1.2	1.2	3.55	5.65	3.85	1.9	1.45	....
17	1.0	1.15	1.2	1.2	3.6	5.65	3.7	1.85	1.4	....
18	1.0	1.15	1.2	1.2	3.6	5.65	3.65	1.8	1.4	....
19	1.1	1.2	1.2	1.2	3.65	5.45	3.6	1.8	1.4	....
20	1.1	1.2	1.2	1.2	3.7	5.2	3.5	1.8	1.4	....
21	1.15	1.2	1.2	1.2	3.8	5.1	3.55	1.8	1.4	....
22	1.15	1.2	1.2	1.25	3.95	4.9	3.4	1.85	1.4	....
23	1.2	1.2	1.2	1.3	4.1	4.8	3.35	1.85	1.35	....
24	1.2	1.2	1.2	1.3	4.25	4.65	3.2	1.85	1.35	....
25	1.2	1.2	1.2	1.35	4.5	4.55	3.2	1.85	1.3	....
26	1.2	1.2	1.2	1.4	4.6	4.5	3.1	1.85	1.3	....
27	1.2	1.2	1.2	1.45	4.65	4.45	2.95	1.85	1.3	....
28	1.2	1.2	1.2	1.5	4.8	4.45	2.8	1.8	1.3	....
29	1.2	....	1.2	1.6	5.0	4.4	2.8	1.8	1.3	....
30	1.2	....	1.2	1.65	5.0	4.35	2.8	1.75	1.3	....
31	1.2	....	1.2	....	4.85	....	2.75	1.75	....	....

[a] Water shut off of Jackson Lake Dam October 13 to December 24, 1906.

Rating table for South Fork of Snake River at Moran, Wyo., for 1904–1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.80	330	1.90	1,007	3.00	1,967	4.10	3,280	5.20	5,080
0.90	374	2.00	1,084	3.10	2,070	4.20	3,420	5.30	5,265
1.00	422	2.10	1,163	3.20	2,175	4.30	3,565	5.40	5,450
1.10	474	2.20	1,244	3.30	2,285	4.40	3,715	5.50	5,640
1.20	530	2.30	1,327	3.40	2,400	4.50	3,870	5.60	5,830
1.30	590	2.40	1,412	3.50	2,515	4.60	4,030	5.70	6,025
1.40	653	2.50	1,499	3.60	2,635	4.70	4,195	5.80	6,220
1.50	719	2.60	1,588	3.70	2,760	4.80	4,365		
1.60	788	2.70	1,679	3.80	2,885	4.90	4,540		
1.70	859	2.80	1,772	3.90	3,015	5.00	4,720		
1.80	932	2.90	1,868	4.00	3,145	5.10	4,900		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 9 discharge measurements made during 1903–1906 and is well defined.

Monthly discharge of South Fork of Snake River at Moran, Wyo., for 1906.

[Drainage area, 820 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	530	374	449	27,600	0.548	0.63
February	530	474	511	28,380	.623	.65
March	560	530	532	32,700	.649	.75
April	823	530	572	34,000	.698	.78
May	4,720	859	2,450	151,000	2.99	3.45
June	5,930	3,640	4,480	267,000	5.46	6.09
July	3,720	1,720	2,820	173,000	3.44	3.97
August	1,680	895	1,120	68,800	1.36	1.57
September	859	590	708	42,100	.863	.96
October 1–12	560	474	526	12,500	.641	.29
The period	....	....	....	837,000	....	....

NOTE.—Values are rated as follows: January to April, September, and October, good; May to August, excellent. Flow assumed unaffected by ice conditions.

SOUTH FORK OF SNAKE RIVER NEAR LYON, IDAHO.

This station was established April 18, 1903. It is located on the old site of Wedekind's Ferry, between Lyon and Swan Valley, at the upper end of Conant Valley. It is about 45 miles from Idaho Falls, Idaho. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 103, where are given also references to publications that contain data for previous years.

Discharge measurements of South Fork of Snake River near Lyon, Idaho, in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 21	E. C. La Rue	292	2,370	5.80	15,900
June 11	do	295	2,580	6.45	19,500
June 12	do	209	2,670	6.85	20,600

Daily gage height, in feet, of South Fork of Snake River near Lyon, Idaho, for 1906.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1		1.05	0.95	3.5	6.55	5.25	3.35	2.2	1.65	1.25
2		1.05	1.1	3.5	6.3	5.6	3.25	2.2	1.6	1.2
3		1.0	1.1	3.7	6.2	5.7	3.25	2.1	1.6	1.2
4		.9	.95	4.3	6.35	5.7	3.2	2.1	1.65	1.25
5		.8	.9	4.4	6.65	5.6	3.1	2.05	1.65	1.25
6		.7	.9	4.0	6.9	5.65	3.05	2.05	1.6	1.2
7		.7	.95	3.85	6.7	5.6	3.0	2.0	1.6	1.2
8		.7	1.2	4.0	6.3	5.5	2.9	2.0	1.6	1.2
9		.7	1.35	4.3	6.1	5.4	2.8	2.0	1.55	1.2
10		.7	1.45	4.65	6.1	5.35	2.7	2.0	1.55	1.2
11		.7	1.5	5.0	6.4	5.3	2.6	1.95	1.55	1.2
12		.4	1.6	5.2	7.0	5.2	2.5	1.95	1.5	1.2
13		.4	1.5	5.55	7.7	5.15	2.55	1.9	1.55	1.2
14		.6	1.5	6.15	7.9	5.2	2.55	1.95	1.5	1.5
15		.6	1.6	6.4	7.6	5.0	2.5	2.0	1.45	1.7
16		.6	1.8	6.2	7.5	4.8	2.4	1.95	1.4	1.55
17		.5	2.1	5.5	7.4	4.7	2.35	1.9	1.4	1.4
18	(a)	.5	2.4	5.15	7.1	4.7	2.35	1.9	1.3	1.2
19	1.7	.7	2.5	5.05	6.6	4.65	2.4	1.85	1.3	1.1
20	1.3	.7	2.6	5.35	6.2	4.4	2.5	1.85	1.25	.9
21	1.4	.8	2.85	5.8	6.0	4.3	2.6	1.8	1.2	.9
22	1.4	.8	3.2	5.7	6.0	4.3	2.8	1.8	1.2	.65
23	1.3	.8	3.6	5.7	5.95	4.3	2.9	1.75	1.3	.55
24	1.2	.8	3.7	6.35	5.65	4.2	2.85	1.75	1.25	.75
25	1.15	.9	3.55	7.2	5.5	4.05	2.7	1.75	1.3	.9
26	1.1	.9	3.2	7.15	5.4	3.9	2.6	1.7	1.3	.9
27	1.1	.9	3.0	6.9	5.5	3.8	2.5	1.7	1.25	.8
28	1.05	.9	3.0	7.25	5.7	3.65	2.4	1.7	1.25	.75
29		.9	3.2	7.55	5.55	3.5	2.3	1.65	1.25	.75
30		.9	3.5	7.15	5.2	3.4	2.3	1.65	1.25	.6
31		.95		6.9		3.3	2.2		1.25	(b)

[a] Frozen over, January 1 to February 18.

[b] December 1, record discontinued for the winter.

Rating table for South Fork of Snake River near Lyon, Idaho, for 1906.

Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.40	1,700	1.50	3,000	2.60	5,090	3.70	7,850	5.40	14.160
0.50	1,800	1.60	3,155	2.70	5,310	3.80	8,150	5.60	15,010
0.60	1,900	1.70	3,320	2.80	5,530	3.90	8.450	5.80	15,900
0.70	2,005	1.80	3,495	2.90	5,750	4.00	8,760	6.00	16,830
0.80	2,115	1.90	3,680	3.00	5,980	4.20	9,420	6.20	17,790
0.90	2,225	2.00	3,870	3.10	6,220	4.40	10,150	6.40	18,760
1.00	2,340	2.10	4,065	3.20	6.470	4.60	10,920	6.60	19,750
1.10	2,460	2.20	4,265	3.30	6,730	4.80	11,710	6.80	20.750
1.20	2,585	2.30	4,465	3.40	7,000	5.00	12,520	7.00	21,760
1.30	2,715	2.40	4,670	3.50	7,208	5.20	13,340	8.00	27,060
1.40	2,855	2.50	4,880	3.60	7,560				

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903-1906 and is well defined.

Monthly discharge of South Fork of Snake River near Lyon, Idaho, for 1906.

[Drainage area, 5,480 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
February (19-28)	3,320	2,400	2,690	53,300	0.491	0.18
March	2,400	1,700	2,080	128,000	.379	.44
April	7,850	2,220	4,300	256,000	.786	.88
May	24,600	7,280	14,900	915,000	2.72	3.14
June	26.500	13,300	18,900	1,120,000	3.44	3.84
July	15.400	6,730	11,700	718,000	2.13	2.46
August	6,860	4,260	5,320	327,000	.970	1.12
September	4,260	3,240	3,700	220,000	.675	.75
October	3,240	2,580	2,890	178,000	.528	.61
November	3,320	1,850	2,470	147,000	.450	.50
The period				4,070,000		

NOTE.—Values for 1906 are excellent.

BUFFALO RIVER NEAR ELK, WYO.

On July 31, 1906, a temporary station was established at the wagon bridge on Buffalo River, 300 feet above its junction with South Fork of Snake River.

The gage is a vertical staff nailed to the middle pier of the bridge and was read by the Government engineers during the construction of the temporary dam at Jackson Lake.

Discharge measurements of Buffalo River near Elk, Wyo., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Dis-charge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
August 14	W. G. Davies	74	218	4.43	352
August 25	E. C. La Rue	74.5	199	4.48	370

Daily gage height, in feet, of Buffalo River near Elk, Wyo., in 1906.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Day.	July.	Aug.	Sept.	Oct.	Nov.
1	......	4.8	4.15	4.0	3.9	17	......	4.3	4.1	3.9	4.0
2	......	4.75	4.15	4.0	3.9	18	......	4.25	4.1	4.0	4.0
3	......	4.75	4.1	4.0	3.9	19	......	4.35	4.1	4.0	4.0
4	......	4.8	4.1	4.0	3.9	20	......	4.45	4.1	4.0	4.0
5	......	4.7	4.1	4.0	3.9	21	......	4.5	4.1	4.0	(a)
6	......	4.6	4.1	4.0	3.9	22	......	4.55	4.1	4.0	......
7	......	4.6	4.1	4.0	3.9	23	......	4.6	4.1	4.0	......
8	......	4.55	4.1	4.0	3.9	24	......	4.55	4.1	4.0	......
9	......	4.5	4.1	4.0	3.9	25	......	4.5	4.1	3.9	......
10	......	4.4	4.05	3.9	3.9	26	......	4.4	4.0	3.9	......
11	......	4.4	4.05	3.9	4.0	27	......	4.35	4.0	3.9	......
12	......	4.45	4.05	3.9	4.0	28	......	4.3	4.0	3.9	......
13	......	4.5	4.1	3.9	4.0	29	......	4.25	4.0	3.9	......
14	......	4.5	4.1	3.9	4.0	30	......	4.2	4.0	3.9	......
15	......	4.4	4.1	3.9	4.0	31	4.8	4.2	......	3.9	......
16	......	4.3	4.1	3.9	4.0						

[a] Record discontinued for the winter.

PACIFIC CREEK NEAR MORAN, WYO.

On July 31, 1906, a temporary station was established at the wagon bridge on Pacific Creek, 500 feet above its junction with South Fork of Snake River.

The gage is a vertical staff nailed to the right abutment pier of the bridge. The gage readings were taken by the Government engineers during the construction of the temporary storage dam at Jackson Lake.

Discharge measurements of Pacific Creek near Moran, Wyo., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
August 14	W. G. Davies	31	90	6.45	96
August 25	E. C. La Rue	29	77	6.60	103

Daily gage height, in feet, of Pacific Creek near Moran, Wyo., for 1906.

Day.	Aug.	Sept.	Oct.	Nov.	Day.	July.	Aug.	Sept.	Oct.
1	6.65	6.3	6.2	6.15	17		6.35	6.3	6.2
2	6.65	6.3	6.2	6.15	18		6.3	6.3	6.25
3	6.7	6.3	6.15	6.15	19		6.4	6.3	6.25
4	6.8	6.3	6.15	6.15	20		6.5	6.3	6.25
5	6.7	6.3	6.15	6.15	21		6.5	6.3	6.2
6	6.6	6.3	6.15	6.15	22		6.6	6.3	6.2
7	6.6	6.3	6.15	6.15	23		6.65	6.25	6.2
8	6.6	6.3	6.1	6.15	24		6.65	6.25	6.2
9	6.55	6.3	6.1	6.15	25		6.55	6.25	6.2
10	6.5	6.3	6.1	6.15	26		6.5	6.25	6.2
11	6.45	6.25	6.1	6.15	27		6.45	6.25	6.2
12	6.45	6.25	6.05	(a)	28		6.45	6.2	6.2
13	6.45	6.3	6.05	....	29		6.4	6.2	6.2
14	6.45	6.3	6.05	....	30		6.35	6.2	6.2
15	6.4	6.3	6.1	....	31	6.7	6.35	....	6.2
16	6.35	6.3	6.15	....					

[a] Record discontinued for the winter.

BLACKFOOT RIVER NEAR PRESTO, IDAHO.

This station was established April 17, 1903. It is located on the ranch of James Just, 2 miles west of Presto and about 15 miles from Blackfoot, Idaho. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 106, where are given also references to publications that contain data for previous years.

Discharge measurements of Blackfoot River near Presto, Idaho, in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 6	E. C. La Rue	56	293	4.06	939
May 20	do	56	288	4.04	932
June 10	do	56	254	3.40	759
August 5	do	53	111	.05	94

Daily gage height, in feet, of Blackfoot River near Presto, Idaho, for 1906.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	....	0.8	4.45	4.1	1.2	0.1	0.5	0.75	1.0
2	....	.85	4.3	4.15	1.2	.05	.45	.75	.95
3	....	.8	4.2	4.05	1.25	.05	.5	.8	1.0
4	....	.9	4.15	4.1	1.2	.05	.5	.75	1.0
5	....	.95	4.15	4.1	1.15	.05	.5	.8	1.05
6	....	.9	4.05	3.95	1.1	.05	.7	.8	1.05
7	....	.9	4.0	3.75	1.0	.0	.6	.8	.95
8	0.7	.85	3.9	3.6	.95	.0	.6	.8	.95
9	.8	.9	3.65	3.5	.9	.05	.55	.75	1.0
10	.6	.7	3.4	3.35	.9	.1	.55	.7	1.0
11	.7	.95	3.15	3.2	.9	.1	.5	.8	1.0
12	.7	1.0	3.0	3.0	.7	.15	.55	.8	1.1
13	.6	.9	2.75	2.7	.65	.4	.6	.8	1.05
14	.6	.95	2.9	2.5	.65	.2	.6	.9	1.0
15	.7	1.4	3.45	2.35	.6	.2	.55	.8	1.05
16	.8	1.5	3.75	2.2	.5	.2	.5	.85	1.05
17	.8	1.7	3.55	2.05	.55	.25	.6	.9	1.1
18	.9	1.95	3.7	2.0	.55	.3	.6	.85	1.15
19	.8	2.5	4.0	2.0	.4	.35	7	.85	1.1
20	.75	2.85	4.1	1.85	.35	.3	.75	.9	1.3
21	.7	3.3	3.8	1.7	.3	.3	.75	.9	1.45
22	.7	4.1	3.55	1.8	.2	35	.75	1.0	1.4
23	.9	5.1	3.3	1.75	.15	.3	.8	.95	1.5
24	1.7	5.5	2.9	1.7	.15	.3	.8	1.0	1.6
25	.85	5.5	2.95	1.55	.15	.35	.7	.9	1.6
26	.7	5.35	2.8	1.5	.1	.4	.65	.9	1.55
27	.75	5.1	2.9	1.4	.15	.45	.65	.95	1.6
28	.8	5.0	3.3	1.4	.1	.45	.7	.9	1.6
29	.8	4.7	3.55	1.25	.1	.5	.7	.9	1.9
30	.75	4.5	3.7	1.15	.1	.5	.7	.9	1.9
31	.9	....	3.8	....	.1	.5	....	.95	....

Rating table for Blackfoot River near Presto, Idaho, for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.00	59	0.90	182	1.80	345	2.70	548	4.20	995
.10	70	1.00	199	1.90	365	2.80	573	4.40	1,070
.20	82	1.10	216	2.00	386	2.90	598	4.60	1,150
.30	94	1.20	233	2.10	407	3.00	624	4.80	1,250
.40	107	1.30	251	2.20	429	3.20	679	5.00	1,350
.50	121	1.40	269	2.30	451	3.40	738	5.20	1,450
.60	135	1.50	287	2.40	474	3.60	798	5.40	1,570
.70	150	1.60	306	2.50	498	3.80	858		
.80	166	1.70	325	2.60	523	4.00	925		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904-1906 and is well defined.

Monthly discharge of Blackfoot River near Presto, Idaho, for 1906.

[Drainage area, 1,020 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
March 8-31	325	135	165	7,860	0.162	0.14
April	1,630	150	593	35,300	.584	.65
May	1,090	560	801	49,200	.788	.91
June	977	224	551	32,800	.542	.60
July	242	70	139	8,550	.137	.16
August	121	59	87	5,350	.086	.10
September	166	114	138	8,210	.136	.15
October	199	150	174	10,700	.171	.20
November	365	190	240	14,300	.236	.26
The period				172,000		

NOTE.—Values are rated as follows: April to June, excellent; March, July, and September to November, good; August, fair.

BIG LOST RIVER NEAR MACKAY, IDAHO.

This station was established November 12, 1903, and was discontinued September 1, 1906. It is located 3½ miles above Mackay, Idaho, above "The Narrows." The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 108, where are given also references to publications that contain data for previous years.

Discharge measurements of Big Lost River near Mackay, Idaho, in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 21	E. C. La Rue	36	84	2.60	140
May 8	do	38	105	3.17	267
May 24	do	42	134	3.95	498
June 14	do	90	298	6.25	1,470
August 7	do	40	108	3.20	324

Daily gage height, in feet, of Big Lost River near Mackay, Idaho, for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1	2.7	2.65	2.65	2.65	2.65	4.1	4.7	3.5
2	2.7	2.65	2.65	2.65	2.65	4.05	4.65	3.5
3	2.7	2.65	2.65	2.65	2.65	4.0	5.05	3.45
4	2.7	2.65	2.65	2.65	2.65	4.2	5.3	3.4
5	2.7	2.65	2.6	2.65	2.8	4.6	5.4	3.3
6	2.7	2.65	2.6	2.65	2.9	4.6	5.6	3.25
7	2.7	2.65	2.6	2.7	3.1	4.5	5.5	3.15
8	2.7	2.65	2.6	2.7	3.3	4.25	5.4	3.1
9	2.7	2.65	2.6	2.7	3.55	4.2	5.4	3.05
10	2.7	2.65	2.6	2.7	3.8	4.15	5.2	3.0
11	2.7	2.65	2.6	2.7	4.3	5.3	5.1	2.95
12	2.7	2.65	2.6	2.7	4.5	5.8	5.1	2.95
13	2.7	2.65	2.6	2.7	4.7	5.8	5.6	3.2
14	2.7	2.65	2.6	2.7	4.65	6.2	5.65	3.15
15	2.7	2.65	2.6	2.65	4.7	5.8	5.5	3.05
16	2.7	2.65	2.6	2.65	4.6	5.7	5.1	3.0
17	2.7	2.65	2.6	2.65	4.4	5.5	4.9	3.0
18	2.7	2.65	2.6	2.65	4.25	5.4	4.85	3.0
19	2.7	2.65	2.6	2.65	4.0	5.3	4.6	2.95
20	2.7	2.65	2.6	2.65	4.0	5.2	4.5	2.95
21	2.7	2.65	2.6	2.65	4.1	5.2	4.4	2.95
22	2.7	2.65	2.6	2.65	4.0	5.2	4.35	3.2
23	2.7	2.65	2.6	2.65	3.95	5.1	4.2	3.4
24	2.7	2.65	2.6	2.65	3.95	4.85	4.05	3.4
25	2.7	2.65	2.6	2.65	4.0	4.7	3.9	3.4
26	2.7	2.65	2.6	2.65	4.1	4.9	3.75	3.35
27	2.7	2.65	2.65	2.65	4.4	5.1	3.65	3.3
28	2.7	2.65	2.65	2.65	4.4	5.25	3.6	3.2
29	2.7	....	2.65	2.65	4.4	5.0	3.55	3.1
30	2.7	....	2.65	2.65	4.25	4.7	3.5	3.0
31	2.65	....	2.65	....	4.1	....	3.5	3.0

Rating table for Big Lost River near Mackay, Idaho, for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.50	129	3.30	302	4.10	566	4.90	886	5.70	1,227
2.60	145	3.40	331	4.20	602	5.00	928	5.80	1,271
2.70	163	3.50	362	4.30	640	5.10	970	5.90	1,315
2.80	183	3.60	395	4.40	680	5.20	1,012	6.00	1,360
2.90	205	3.70	429	4.50	720	5.30	1,054	6.20	1,450
3.00	227	3.80	463	4.60	760	5.40	1,097		
3.10	250	3.90	497	4.70	802	5.50	1,140		
3.20	275	4.00	531	4.80	844	5.60	1,183		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904-1906 and is well defined.

Monthly discharge of Big Lost River near Mackay, Idaho, for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
January	163	154	163	10,000
February	154	154	154	8,550
March	154	145	148	9,100
April	163	154	156	9,280
May	802	154	507	31,200
June	1,450	531	914	54,400
July	1,200	362	814	50,000
August	362	216	270	16,600
The period				189,000

NOTE.—Values are rated as excellent. Flow assumed unaffected by ice conditions.

BIG LOST RIVER NEAR CHILLY, IDAHO.

This station was established April 25, 1904, and was discontinued August 31, 1906. It was located at Howell's ranch, the last one on the left bank, about 25 miles upstream from Mackay, 7 miles from Chilly, and about 3 miles above Kinickinick Point.

The gage is a vertical staff on the left bank one-half mile above the cable, 300 feet from Mr. Howell's house. Until April 20, 1906, the gage was located one-quarter mile from the house. It was moved in order to place it on the main channel. During 1906 it was read once each day by Miss Maud Howell. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 110, where are given also references to publications that contain data for previous years.

Discharge measurements of Big Lost River near Chilly, Idaho, in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 21	E. C. La Rue	81	149	2.50	233
April 22	do	81	163	2.67	300
May 8	do	84	216	3.35	740
May 9	do	85	239	3.60	909
May 24	do	83	213	3.28	651
June 14	do	92	308	4.30	1,790
August 7	do	81.5	166	2.68	310
August 8	do	81.5	163	2.70	318

Daily gage height, in feet, of Big Lost River near Chilly, Idaho, for 1906.

Day.	Apr.	May.	June.	July.	Aug.	Day.	Apr.	May.	June.	July.	Aug.
1		2.75	3.2	3.6	2.8	17		3.35	4.1	3.6	2.5
2		2.9	3.1	3.8	2.8	18		3.3	3.85	3.5	2.5
3		3.1	3.2	3.9	2.75	19		3.2	3.75	3.3	2.6
4		3.35	3.4	4.0	2.7	20	(a)	3.4	3.7	3.25	2.6
5		3.3	3.5	3.95	2.7	21	2.5	3.4	3.85	3.25	2.7
6		3.3	3.5	3.9	2.7	22	2.65	3.3	3.9	3.25	2.7
7		3.3	3.3	4.0	2.7	23	2.9	3.3	3.65	3.2	2.75
8		3.4	3.25	3.85	2.7	24	2.8	3.3	3.5	3.35	2.7
9		3.6	3.3	3.8	2.65	25	2.7	3.4	3.6	3.05	2.6
10		3.8	3.5	3.7	2.6	26	2.65	3.6	3.8	3.2	2.55
11		3.8	3.9	3.75	2.6	27	2.65	3.5	3.8	2.95	2.5
12		3.9	4.55	3.8	2.6	28	2.6	3.4	3.9	2.9	2.5
13		3.8	4.7	4.0	2.7	29	2.7	3.3	3.6	2.85	2.5
14		3.85	4.3	3.9	2.6	30	2.75	3.2	3.45	2.85	2.5
15		3.75	4.15	3.7	2.6	31		3.2	....	2.9	2.5
16		3.5	4.4	3.5	2.5						

[a] Frozen over January 1 to April 20.

Rating table for Big Lost River near Chilly, Idaho, for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.10	90	2.70	320	3.30	660	3.90	1,260	4.50	2,080
2.20	120	2.80	370	3.40	740	4.00	1,380	4.60	2,230
2.30	155	2.90	420	3.50	820	4.10	1,510	4.70	2,380
2.40	195	3.00	475	3.60	910	4.20	1,650		
2.50	235	3.10	530	3.70	1,020	4.30	1,790		
2.60	275	3.20	590	3.80	1,140	4.40	1,930		

Note.—The above table is applicable only for open-channel conditions. It is based on 8 discharge measurements made during 1906 and is well defined.

Monthly discharge of Big Lost River near Chilly, Idaho, for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
April 21-30	420	235	318	6,310
May	1,260	345	770	47,300
June	2,380	530	1,100	65,800
July	1,380	395	885	54,400
August	370	235	288	17,700
The period				192,000

NOTE.—Values are rated as excellent.

BIG WOOD RIVER NEAR SHOSHONE, IDAHO.

This station was established June 5, 1905, and was discontinued December 31, 1906. It was located at A. D. Silva's ranch, 1 mile below the steel wagon bridge and 7 miles northwest of Shoshone, Idaho. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 113, where are given also references to publications that contain data for previous years.

Discharge measurements of Big Wood River near Shoshone, Idaho, in 1905-6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1905.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
July 17	E. C. La Rue	86	112	2.50	63
1906.					
April 9	do	91	297	4.76	767
April 13	do	94	469	6.50	1,810
April 25	do	92	427	6.02	1,510
May 5	do	92	350	5.25	1,060
May 18	do	89	287	4.63	699
June 8	do	89	262	4.31	552
July 6	do	88	249	4.18	502
July 13	do	88	223	3.87	404
July 26	do	86	122	2.70	91

Daily gage height, in feet, of Big Wood River near Shoshone, Idaho, for 1906.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Day.	Mar.	Apr.	May.	June.	July.	Aug.
1	......	3.3	5.05	4.3	3.9	1.95	17	......	7.45	4.95	5.05	3.6	......
2	......	2.5	5.1	4.15	3.8	1.75	18	......	7.1	4.7	4.85	3.4	......
3	......	2.3	5.0	4.0	4.0	......	19	......	6.9	4.5	4.65	3.4	......
4	......	2.2	5.1	4.0	4.1	......	20	......	6.0	4.3	4.55	3.2	......
5	......	2.2	5.25	4.1	4.2	......	21	......	5.8	4.25	4.4	3.1	......
6	......	2.3	5.25	4.4	4.2	......	22	......	5.8	4.15	4.3	2.9	......
7	......	3.2	5.15	4.45	4.15	......	23	......	6.0	4.0	4.4	2.8	......
8	......	4.0	5.0	4.35	4.2	......	24	......	6.2	3.9	4.2	3.0	......
9	......	4.6	5.0	4.2	4.2	......	25	......	6.1	3.8	4.05	2.8	......
10	......	5.4	5.0	4.0	4.25	......	26	2.2	5.9	3.75	3.75	2.75	......
11	......	5.7	5.05	4.0	4.05	......	27	2.35	5.7	4.05	4.1	2.6	......
12	......	6.4	5.05	4.1	4.0	......	28	2.35	5.4	4.3	4.2	2.4	......
13	......	6.4	5.1	4.9	3.9	......	29	3.1	5.15	4.5	4.4	2.35	......
14	......	6.9	5.1	5.35	3.9	......	30	3.4	5.1	4.5	4.15	2.2	......
15	......	8.0	5.2	5.1	4.0	......	31	3.3	......	4.4	......	2.0	......
16	......	7.9	5.2	4.95	3.8	......							

NOTE.—The river was dry January 1 to March 25 and August 2 to December 31.

Rating table for Big Wood River near Shoshone, Idaho, for 1905–6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.90	0	2.90	124	3.90	410	4.90	845	6.60	1,870
2.00	9	3.00	145	4.00	445	5.00	900	6.80	2,010
2.10	19	3.10	170	4.10	480	5.20	1,010	7.00	2,150
2.20	29	3.20	195	4.20	515	5.40	1,130	7.20	2,300
2.30	40	3.30	220	4.30	550	5.60	1,230	7.40	2,450
2.40	51	3.40	250	4.40	590	5.80	1,370	7.60	2,610
2.50	63	3.50	280	4.50	635	6.00	1,490	7.80	2,780
2.60	76	3.60	310	4.60	685	6.20	1,610	8.00	2,950
2.70	90	3.70	340	4.70	735	6.40	1,740		
2.80	106	3.80	375	4.80	790				

NOTE.—The above table is applicable for open-channel conditions. It is based on 10 discharge measurements made during 1905–6 and is well defined.

Monthly discharge of Big Wood River near Shoshone, Idaho, for 1905–6.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1905.[a]				
June 5–30	410	115	260	13,400
July	115	0	58	3,570
The period				17,000
1906.[b]				
January			0	0
February			0	0
March	250	0	24	1,480
April	2,950	29	1,240	73,500
May	1,040	357	760	46,700
June	1,100	357	604	35,900
July	532	9	300	18,400
August	4	0	.13	8
September			0	0
October			0	0
November			0	0
December			0	0
The year				176,000

[a] Values for 1905 are rated as good.

[b] Values for 1906 are rated as follows: March and August, approximate; April to June, excellent; July, good.

NOTE.—River dry July 28 to December 31, 1905.

SUCCOR CREEK NEAR HOMEDALE, IDAHO.

This station was established March 19, 1903. It was originally located at a small truss bridge built to carry a flume, about one-half mile above the mouth of the river. The station was moved January 31, 1905, about one-half mile upstream to a location 1 mile west of Homedale and about 17 miles from Caldwell, the nearest railroad station. It is near the Caldwell-Jordan Valley stage road, 1 mile west of Mussel's ferry on Snake River, one-fourth mile below the head of the lowest ditch on Succor Creek, and about three-fourths mile above the mouth of the creek. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 114, where are given also references to publications that contain data for previous years.

Discharge measurements of Succor Creek near Homedale, Idaho, in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 9	E. C. La Rue	35	46	3.58	126
March 10	do	40	58	3.90	216
April 3	do	45	71	4.35	370
June 7	do	36	47	3.50	125
July 3	do	....	.30	2.10	.2

Daily gage height, in feet, of Succor Creek near Homedale, Idaho, for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Dec.
1	1.95	2.6	3.25	4.6	3.3	3.95	....
2	1.95	2.55	3.05	4.6	3.3	3.9	....
3	1.95	2.55	3.05	4.2	3.25	3.6	....
4	1.95	2.6	3.6	3.9	3.2	3.6	....
5	1.95	2.65	3.25	4.0	3.2	3.75	2.0
6	1.95	2.65	3.25	4.3	3.1	3.6	2.1
7	1.95	2.6	3.25	4.2	2.95	3.5	2.25
8	1.95	2.6	3.3	4.4	2.9	3.5	2.3
9	1.95	2.55	3.5	4.5	2.9	3.45	2.3
10	1.95	2.5	3.8	4.3	2.85	3.4	2.3
11	2.0	2.6	3.4	3.8	2.8	3.2	2.3
12	2.0	2.55	3.1	3.5	3.2	3.1	2.3
13	2.3	2.55	3.1	3.4	3.05	3.0	2.3
14	2.2	2.6	3.1	3.5	2.95	2.95	2.3
15	2.3	2.8	3.1	3.6	3.0	2.9	2.3
16	2.3	3.45	2.75	3.8	2.9	3.0	2.3
17	2.3	3.5	2.7	3.8	2.8	2.9	2.3
18	2.4	3.4	2.8	3.7	2.75	2.8	2.3
19	3.75	4.2	2.8	3.7	2.7	2.7	2.3
20	2.5	3.25	2.95	3.6	2.65	2.6	2.35
21	2.5	3.4	3.0	3.8	2.65	2.45	2.3
22	2.5	3.25	3.95	3.8	2.65	2.45	2.3
23	2.65	3.0	4.0	3.7	2.55	2.45	2.3
24	3.25	3.0	4.6	3.7	2.5	2.2	2.35
25	3.3	3.05	4.75	3.7	2.45	2.15	2.4
26	3.3	2.95	4.2	3.5	2.4	2.1	2.35
27	2.9	3.3	4.3	3.45	2.3	2.45	2.3
28	2.8	4.15	4.0	3.35	2.7	2.25	2.45
29	2.7	....	3.9	3.3	4.75	2.1	2.5
30	2.6	....	4.2	3.3	4.2	2.0	2.45
31	2.65	....	4.7	....	4.0	....	2.5

NOTE.—Creek dry June 30 to December 4, 1906.

Rating table for Succor Creek near Homedale, Idaho, for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.00	0.0	2.60	18	3.20	71	3.80	184	4.40	389
2.10	.2	2.70	24	3.30	83	3.90	214	4.50	426
2.20	3	2.80	31	3.40	97	4.00	247	4.60	464
2.30	6	2.90	40	3.50	114	4.10	281	4.70	502
2.40	9	3.00	50	3.60	134	4.20	316	4.80	542
2.50	13	3.10	60	3.70	157	4.30	352		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 5 discharge measurements made during 1906, and is not well defined below 3.5 feet.

Monthly discharge of Succor Creek near Homedale, Idaho, for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
January	170	0	20.7	1,270
February	316	13	61.9	3,440
March	522	24	158	9,720
April	464	83	210	12,500
May	522	6	71.2	4,380
June	230	0	64.3	3,830
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0	0
November	0	0	0	0
December	13	0	5.8	357
The year				35,500

NOTE.—Values are rated as follows: January, February, May, June, and December, approximate; March and April, good. Flow assumed unaffected by ice during winter period.

OWYHEE RIVER NEAR OWYHEE, OREG.

This station was established August 27, 1903, at the county bridge 1½ miles from Owyhee, Oreg. Owyhee ditch takes water from the river about 6 miles above. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 116, where are given also references to publications that contain data for previous years.

Discharge measurements of Owyhee River near Owyhee, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 8	R. S. Hall	273	556	3.58	760
March 31	do	290	1,870	8.32	9,620
April 13	do	286	1,720	7.61	7,780
April 27	do	286	1,470	6.72	5,440
June 13	do	282	940	5.02	2,290
November 29[a]	Stevens and McGlashan	120	192	2.80	231

[a] Slush ice running. Right channel entirely frozen.

Daily gage height, in feet, of Owyhee River near Owyhee, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.97	3.42	3.42	9.00	5.90	7.12	3.97	2.02	2.02	2.37	2.32	2.75
2	2.97	3.37	3.42	8.97	5.87	7.10	3.87	2.04	2.02	2.37	2.32	2.75
3	2.97	3.32	3.42	7.78	5.82	6.52	3.72	2.00	2.02	2.37	2.32	2.75
4	2.97	3.37	3.42	7.24	5.79	6.42	3.62	1.97	2.02	2.37	2.32	2.75
5	2.97	3.37	3.42	7.04	5.77	6.27	3.67	1.92	2.02	2.37	2.32	2.75
6	3.02	3.37	3.42	7.02	5.72	6.02	3.47	1.92	2.02	2.37	2.32	2.75
7	3.02	3.37	3.42	7.14	5.67	5.87	3.32	1.92	2.02	2.42	2.34	2.75
8	3.02	3.37	3.57	8.12	5.57	5.74	3.22	1.92	2.02	2.37	2.37	2.75
9	3.02	3.37	3.90	8.87	5.47	5.52	3.22	1.92	2.02	2.37	2.40	2.75
10	3.02	3.37	4.02	9.00	5.37	5.67	3.42	1.92	2.02	2.37	2.42	2.75
11	3.02	3.27	4.10	8.60	5.27	5.57	2.97	1.92	2.02	2.30	2.45	2.75
12	3.22	3.32	4.12	8.22	5.37	5.47	2.97	1.92	2.02	2.30	2.47	2.75
13	3.22	3.27	4.12	7.72	5.27	5.37	2.92	1.92	2.04	2.30	2.52	2.75
14	3.22	3.22	4.12	7.32	5.22	5.27	2.92	1.92	2.04	2.30	2.57	2.75
15	3.22	3.22	4.12	7.32	5.17	5.07	2.90	1.92	2.02	2.30	2.60	2.75

Daily gage height, in feet, of Owyhee River near Owyhee, Oreg., for 1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.
16	3.22	3.22	4.17	7.42	5.12	4.92	2.87	1.92	2.02	2.30	2.64	2.75
17	3.22	3.17	4.07	7.57	5.07	4.77	2.87	1.92	2.07	2.30	2.70	2.75
18	3.22	2.92	3.87	7.42	5.02	4.57	2.82	1.97	2.14	2.30	2.72	2.75
19	3.60	3.00	3.70	7.32	4.97	4.47	2.82	1.97	2.14	2.30	2.72	2.75
20	3.90	3.07	3.57	7.27	4.92	4.47	2.82	1.97	2.14	2.32	2.72	2.75
21	3.42	3.06	3.47	6.87	4.82	4.39	2.80	1.97	2.14	2.32	2.72	2.75
22	3.42	3.17	3.47	6.82	4.67	4.32	2.72	1.97	2.14	2.32	2.72	2.75
23	3.42	3.32	5.70	6.72	4.57	4.17	2.62	1.97	2.14	2.32	2.72	2.75
24	3.42	3.37	5.44	6.52	4.42	4.11	2.57	1.97	2.14	2.32	2.72	2.76
25	3.47	3.52	6.61	6.62	4.27	4.02	2.47	2.02	2.14	2.32	2.72	2.75
26	3.47	3.42	7.62	6.52	4.22	3.97	2.32	2.02	2.14	2.32	2.72	2.75
27	3.47	3.37	8.04	6.47	4.14	3.92	2.27	2.02	2.37	2.32	2.67	2.75
28	3.47	3.37	7.94	6.42	4.12	3.87	2.22	2.02	2.37	2.32	2.67	2.80
29	3.47	....	8.02	6.32	4.62	3.90	2.17	2.02	2.37	2.32	2.75	2.85
30	3.47	....	7.87	6.12	6.62	3.97	2.12	2.02	2.37	2.32	2.75	2.85
31	3.47	....	8.52	....	7.07	....	2.07	2.02	....	2.32	....	2.90

Note.—There was probably some obstruction from ice during the latter part of November and December. No correction has been made in discharge.

Rating table for Owyhee River near Owyhee, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.90	15	2.90	295	3.90	995	4.90	2,100	6.80	5,680
2.00	25	3.00	350	4.00	1,080	5.00	2,240	7.00	6,160
2.10	35	3.10	410	4.10	1,170	5.20	2,540	7.20	6,660
2.20	50	3.20	475	4.20	1,270	5.40	2,860	7.40	7,180
2.30	70	3.30	540	4.30	1,370	5.60	3,210	7.60	7,700
2.40	95	3.40	610	4.40	1,480	5.80	3,580	7.80	8,240
2.50	125	3.50	680	4.50	1,590	6.00	3,960	8.00	8,780
2.60	160	3.60	755	4.60	1,710	6.20	4,360	9.00	11,570
2.70	200	3.70	830	4.70	1,830	6.40	4,780		
2.80	245	3.80	910	4.80	1,960	6.60	5,220		

Note.—This table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905-6 and is well defined.

Monthly discharge of Owyhee River near Owyhee, Oreg., for 1906.

[Drainage area, 9,880 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	995	333	519	31,900	0.052	0.06
February	695	306	533	29,600	.054	.06
March	10,200	624	2,700	166,000	.272	.31
April	11,600	4,200	7,250	432,000	.733	.82
May	6,340	1,190	2,700	166,000	.270	.31
June	6,460	970	2,640	157,000	.267	.30
July	1,060	32	367	22,600	.037	.04
August	29	17	21.5	1,320	.0022	.002
September	88	27	39.6	2,360	.0040	.004
October	102	70	78.2	4,810	.0079	.01
November	222	75	152	9,040	.015	.02
December	295	222	228	14,000	023	.03
The year	11,600	17	1,210	1,040,000	.122	1.97

Note.—Values are rated as good.

BOISE RIVER NEAR HIGHLAND, IDAHO.

This station was established on July 27, 1905, to replace the Boise station. It is located 2 miles below the mouth of Moores Creek, 3 miles southwest of Highland post-office, about 8 miles above the old Boise station, and 15 miles east of Boise, the nearest railroad point. The conditions and the bench marks are described in Water-Supply Paper No. 178, page 121.

Discharge measurements of Boise River near Highland, Idaho, in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 3	E. C. La Rue	180	309	3.85	1,130
April 4	do	220	831	6.38	3,150
April 15	do	233	1,260	8.20	5,630
May 16	do	235	1,520	9.40	7,260
June 6	do	230	1,340	8.80	6,390
June 29	do	226	1,160	7.90	5,040
July 11	do	220	844	6.55	3,090
July 16	do	216	669	5.75	2,350
July 20	do	202	550	5.10	1,750
July 24	do	193	442	4.60	1,480
July 27	do	188	368	4.20	1,310

Daily gage height, in feet, of Boise River near Highland, Idaho, for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	3.3	3.5	4.0	7.55	9.1	8.35	7.25	3.9	3.4	3.15	3.4
2	3.3	3.45	3.85	6.9	9.2	8.2	7.35	3.85	3.4	3.1	3.4
3	3.25	3.45	3.85	6.55	9.5	8.3	7.5	3.8	3.45	3.15	3.4
4	3.3	3.5	3.85	6.4	9.9	8.6	7.55	3.8	3.35	3.25	3.4
5	3.4	3.4	3.85	6.25	9.5	8.65	7.4	3.7	3.3	3.35	3.45
6	3.6	3.45	3.8	6.8	9.35	8.85	7.3	3.65	3.3	3.35	3.45
7	3.4	3.45	3.8	7.4	9.25	8.35	7.2	3.65	3.25	3.3	3.5
8	3.4	3.5	4.0	7.95	9.45	8.35	7.05	3.6	3.25	3.2	3.5
9	3.4	3.5	4.4	8.05	9.55	8.2	6.9	3.55	3.25	3.2	3.55
10	3.5	3.5	4.6	8 3	9.95	8.25	6.7	3.5	3.25	3.15	3.6
11	3.6	3.5	4.5	7.75	10.05	8.5	6.55	3.45	3.25	3.15	3.6
12	3.6	3.6	4.4	7.6	10 3	9.5	6.5	3.4	3.25	3.2	3.5
13	3.5	3.65	4.3	7.7	10.3	9.85	6.3	3.5	3.45	3.3	3.8
14	3.5	3.7	4.1	7.75	10.15	9.15	6.15	3.55	3.5	3.25	5 75
15	3.5	3.75	3.9	8.2	10.1	9.05	5.9	3.5	3.4	3.15	6.0
16	3.5	3.9	3.6	8.6	9.5	8.95	5.75	3.4	3.35	3.25	8 05
17	3.5	4.0	3.4	8 75	8.85	8.95	5.6	3.4	3.3	3.3	5.5
18	3.8	4.1	3.5	8.8	8.5	8.55	5.45	3.35	3 3	3.35	4.6
19	3.7	4.25	3.6	8.85	8.35	8.3	5.3	3.25	3.25	3.3	3.95
20	3.6	4.2	3.8	8.9	8.35	8.15	5.1	3.3	3.25	3.3	3.9
21	3.5	4.1	3.9	9.5	8 35	8.1	4.95	3.3	3.2	3.3	4.0
22	3.7	4.2	4.0	9.9	8.25	8.0	4.85	3.4	3.15	3.3	4.0
23	3.6	4.1	4.3	10.2	8 1	7.9	4.95	3.55	3.15	3.3	3.8
24	3.5	3.95	4.65	9.75	8.15	7.7	4.6	3.65	3.15	3.3	3.7
25	3.5	3.9	5.65	9.5	8.2	7.7	4.45	3.6	3.15	3.3	3.7
26	3.7	3.9	6.2	8.9	9.25	7.8	4.35	3.45	3.15	3.3	3.65
27	3.6	3.85	6.5	8.75	9.05	7.9	4.2	3.45	3.15	3.3	3.65
28	3.5	4.15	6.5	8.7	8 9	8.5	4.15	3.35	3.15	3.35	3.65
29	3.5	....	6.65	8.9	8.85	7.9	4.05	3.45	3.15	3.35	3.55
30	3.4	....	6.75	8.95	8.6	7.5	4.0	3.45	3.15	3.35	3.5
31	3.4	....	7.25	....	8.5	....	3.95	3.4	....	3.35	......

NOTE.—Record discontinued for the winter on December 1.

Rating table for Boise River near Highland, Idaho, for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
3.00	560	4.00	1,240	5.00	1,700	6.00	2,620	8.00	5,180
3.10	600	4.10	1,280	5.10	1,780	6.20	2,840	8.20	5,470
3.20	650	4.20	1,310	5.20	1,860	6.40	3,060	8.40	5,770
3.30	700	4.30	1,350	5.30	1,940	6.60	3,300	8.60	6,070
3.40	750	4.40	1,390	5.40	2,020	6.80	3,540	8.80	6,370
3.50	810	4.50	1,430	5.50	2,110	7.00	3,800	9.00	6,670
3.60	880	4.60	1,470	5.60	2,200	7.20	4,060	10.00	8,240
3.70	960	4.70	1,510	5.70	2,300	7.40	4,340		
3.80	1,060	4.80	1,560	5.80	2,400	7.60	4,620		
3.90	1,160	4.90	1,620	5.90	2,510	7.80	4,900		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 15 discharge measurements made during 1905-6, and is well defined between gage heights 3 feet and 9 feet.

Monthly discharge of Boise River near Highland, Idaho, for 1906.

[Drainage area, 2,610 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec-ft. per sq. mile.	Depth in inches.
January	1,060	675	820	50,400	0.314	0.36
February	1,330	750	1,020	56,800	.391	.41
March	4,130	750	1,630	100,000	.624	.72
April	8,560	2,900	5,630	335,000	2.15	2.40
May	8,720	5,320	6,900	425,000	2.64	3.04
June	8,000	4,480	8,780	344,000	2.21	2.47
July	4,550	1,200	2,630	162,000	1.00	1.15
August	1,160	675	839	51,600	.321	.37
September	810	625	685	40,800	.262	.29
October	725	600	683	42,000	.261	.30
November	5,250	750	1,220	72,800	.468	.52
The period				1,680,000		

NOTE.—Values are rated as excellent. Flow assumed unaffected by ice conditions during the winter months

SEEPAGE INVESTIGATIONS ON BOISE RIVER.

The following is a detailed report of the investigation made by E. C. La Rue during October, 1906, in order to determine the amount of seepage water returning to Boise River between the mouth of its canyon, 8 miles above Boise, and Caldwell Canyon, 2½ miles above Caldwell, Idaho.

The distance by river between the points is 34 miles. This distance was covered on foot and by following the river bank, and the discharge of every diversion and tributary was carefully noted.

The gage reading at the Highland station on Boise River, about 8 miles above the mouth of Boise Canyon, was 3.20 on October 9, 1906, which corresponds to a discharge of 650 second-feet. From here to Boise Canyon the river flows through a narrow rocky canyon and receives no tributaries. Consequently 650 second-feet is the discharge at the mouth of the canyon, just above the New York canal heading. On October 12, 1906, the day the investigation was finished, the gage at the Highland station still read 3.20. Therefore during this period of investigation the uniform available supply of the river above all irrigation was 650 second-feet.

The net seepage will be the difference between the discharge of the river at the upper point, plus all tributaries between the two points of measurement, and the discharge of the river at the lower point, plus all diverted water between the two points in question.

The results are expressed in the following table:

Discharge of Boise River at upper point, plus tributaries.

Date.	Stream.	Locality of heading or place of measurement.	Discharge in second-feet.
1906.			
October 9	Boise River	At mouth of canyon, above New York canal heading.	650
October 9	Waste from sloughs	Between Ninth and Broadway Bridge	.5
October 9	Waste from canals and sloughs.	Between Broadway Bridge and Ridenbaugh canal heading.	2.8
October 10	Waste from Rossi canal	½ mile below Broadway Bridge	17.8
October 10	do	Just above Oregon Short Line Railway bridge.	38.1
October 10	do	Just below Oregon Short Line Railway bridge.	98.6
October 10	Waste	Below Mill slough ditch heading	13.0
October 10	do	From Lower Mill slough ditch	3.0
October 10	do	Just above Phyllis canal heading	1.0
October 10	do	From Eureka canal	3.0
October 11	do	3 miles below Star Bridge	4.0
October 11	Willow Creek waste	½ mile below Middleton	21.1
October 12	Waste Middleton Mill slough.	At Middleton	4.0
October 12	Waste	Just below Farmers' Union canal heading	2.0
October 12	do	Boise City sewer discharge	10.0
	Total		868.9

Discharge of Boise River at lower point, plus all diversions.

Date.	Stream.	Locality of heading or place of measurement.	Discharge in second-feet.
1906.			
October 9	New York canal	Below all waste	95.5
October 9	Ridenbaugh canal	Just below wasteway	209.4
October 9	Rossi canal	Just above wasteway	205.9
October 9	Small diversion	½ mile above Rossi heading	1.0
October 9	Payne ditch	At heading	1.0
October 10	Davis or Mill slough ditch	Below wasteway	20.1
October 10	Joplin ditch	At heading	4.0
October 10	Eureka canal	Below wasteway	9.3
October 10	Phyllis canal	do	58.6
October 11	Boise River	At lower point of measurement, 2½ miles above Caldwell.	95.1
October 11	Caldwell Highline canal	Below all waste	26.7
October 12	Canyon County canal	Below wasteway	9.2
October 12	Small diversion	3 miles above Star	1.0
October 12	Middleton Mill ditch	Below wasteway	35.0
October 12	Middleton Mill slough ditch	do	8.9
October 12	Pioneer or Stewart ditch		0.0
October 12	Ballantyne ditch	Below all waste	1.0
October 12	Dry Creek ditch	Below wasteway	10.8
October 12	Farmers' Union and Valley ditch.	do	61.6
October 12	Boise City ditch	do	9.5
October 12	Perrault ditch	At penitentiary	9.4
	Total		873.0

Investigations similar to the foregoing were made during 1898, 1901, 1902, 1903, and 1905. The results of these investigations, including the summary for 1906, are given below:

Seepage gains in Boise River.

	Sec.-ft.	Sec.-ft.
1898, August 24 to September 2:		
Amount taken out by canals		1,160.0
Amount in river above canals	734	
Amount of measured return water	197	
Total	931	
Amount in river at Caldwell station	31	
Difference		900.0
Gain by seepage in 34 miles		260.0
1901, August 13 to 17:		
Discharge Boise River above New York canal heading		821.0
Discharge Boise River at Caldwell Canyon	73.3	
Amount of measured return water		131.0
Amount taken out by canals	1,140.1	
Gain by seepage in 34 miles		261.4
	1,213.4	1,213.4
1902, August 11 to 15:		
Discharge Boise River at upper point		924.5
Discharge Boise River at lower point	1.5	
Amount of measured return waters		174.4
Amount taken out by canals	1,309.0	
Gain by seepage in 34 miles		211.6
	1,310.5	1,310.5
1903, October 24 to 29:		
Discharge of Boise River at upper point		771.6
Discharge of Boise River at lower point	619.4	
Amount of measured return waters		362.6
Amount taken out by canals	654.4	
Gain by seepage in 34 miles		[a] 139.6
	1,273.8	1,273.8
1905, October 2 to 7:		
Discharge Boise River at upper point		602.0
Discharge Boise River at lower point	106.6	
Amount of measured return waters		82.7
Amount taken out by canals	601.5	
Gain by seepage in 34 miles		23.4
	708.1	708.1

---

[a] Mistakes were found in calculation. The result of 255.3 second-feet gain, as published in Water-Supply Paper No. 100, should read 139.6 second-feet.

1906, October 9 to 12:	Sec.-ft.	Sec.-ft.
Discharge Boise River at upper point		650.0
Discharge Boise River at lower point	95.1	
Amount of measured return water		218.9
Amount taken out by canals	777.9	
Gain by seepage in 34 miles		4.1
	873.0	873.0

PAYETTE RIVER NEAR HORSESHOE BEND, IDAHO.

This station was established February 13, 1906. It is located at a point known as Jerusalem, 5 miles above Horseshoe Bend post-office, Idaho, and about 32 miles from Boise, the most convenient railway point.

The channel is straight for 1,000 feet above and below the station. The water is comparatively swift during all stages. Both banks are firm, rather steep, and not liable to overflow. The bed of the stream is strewn with small smooth bowlders, and is permanent.

Discharge measurements are made by means of a cable and car. The initial point for soundings is the inner face of the pine tree which acts as the right cable support.

The gage, which was read once each day by E. R. Sherard, is inclined and is located on the right bank directly under the cable. The bench mark is a United States Geological Survey aluminum tablet set in the base of the pine tree which is used as the cable support on the right bank; elevation, 12.53 feet above the datum of the gage.

Discharge measurements of Payette River near Horseshoe Bend, Idaho, by E. C. La Rue, in 1906.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 24	253	476	4.21	1,250
April 6	265	811	5.46	3,100
April 16	273	1,060	6.40	5,030
May 3	275	1,200	6.97	6,600
May 15	281	1,530	8.15	9,620
June 27	270	1,110	6.60	5,510
July 10	269	878	5.75	3,630
July 19	260	656	4.95	2,150
August 2	252	498	4.30	1,330

Daily gage height, in feet, of Payette River near Horseshoe Bend, Idaho, in 1906.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1		4.1	5.65	6.8	7.1	6.5	4.35	3.9	3.8	3.95
2		4.0	5.55	6.8	6.75	6.35	4.3	3.85	3.8	3.95
3		4.0	5.4	7.0	6.6	6.3	4.3	3.85	3.8	3.95
4		4.05	5.45	7.15	6.8	6.25	4.25	3.85	3.75	3.95
5		4.0	5.35	7.15	7.15	6.2	4.25	3.8	3.75	3.95
6		4.0	5.5	7.1	7.1	6.15	4.2	3.8	3.75	3.95
7		4.0	5.8	7.1	6.9	6.05	4.2	3.8	3.75	4.0
8		4.1	6.0	7.05	6.9	6.0	4.15	3.8	3.75	4.1
9		4.2	6.1	7.15	6.8	5.95	4.15	3.75	3.75	4.2
10		4.3	6.5	7.4	6.7	5.85	4.1	3.75	3.75	4.25

Daily gage height, in feet, of Payette River, near Horseshoe Bend, Idaho, in 1906—Cont'd.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
11	....	4.35	6.2	7.65	6.65	5.7	4.1	3.75	3.75	4.5
12	....	4.2	6.1	8.0	7.2	5.6	4.15	3.8	3.75	5.0
13	3.9	4.2	6.05	8.1	7.25	5.45	4.15	3.8	3.75	6.0
14	3.9	4.15	6.0	8.1	7.4	5.35	4.2	3.9	3.8	6.4
15	4.0	4.1	6.1	8.1	7.6	5.3	4.15	4.0	3.8	6.4
16	4.05	4.0	6.4	8.0	7.5	5.25	4.1	4.0	3.8	6.0
17	4.05	4.0	6.4	7.6	7.6	5.1	4.0	4.0	3.8	5.5
18	4.05	4.0	6.5	7.25	7.4	5.0	4.0	3.95	3.8	6.0
19	4.1	4.0	6.5	7.05	7.2	4.95	4.05	3.95	3.85	5.5
20	4.15	4.0	6.55	6.9	7.25	4.85	4.05	3.9	3.85	5.2
21	4.15	4.1	6.8	6.9	7.1	4.8	4.0	3.9	3.85	5.0
22	4.2	4.05	7.1	6.8	6.95	4.75	4.0	3.85	3.85	4.9
23	4.2	4.1	7.35	6.85	6.95	4.7	4.0	3.85	3.85	4.8
24	4.1	4.15	7.35	6.85	6.8	4.7	4.0	3.85	3.85	4.7
25	4.05	4.55	7.35	6.85	6.65	4.65	4.0	3.8	3.85	4.7
26	4.0	4.75	7.05	6.95	6.5	4.55	4.0	3.8	3.85	4.65
27	4.0	4.9	6.8	7.05	6.5	4.5	4.0	3.8	3.85	4.65
28	4.1	5.0	6.65	7.5	7.0	4.45	3.95	3.8	3.9	4.6
29	....	5.05	6.65	7.5	6.9	4.45	3.95	3.8	3.9	4.6
30	....	5.15	6.75	7.2	6.85	4.4	3.9	3.8	3.9	4.6
31	....	5.25	....	7.25	....	4.35	3.9	....	3.9	(a)

[a] Record discontinued for the winter.

Rating table for Payette River near Horseshoe Bend, Idaho, for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
3.70	760	4.70	1,800	5.70	3,530	6.70	5,760	7.70	8,430
3.80	850	4.80	1,940	5.80	3,720	6.80	6,020	7.80	8,710
3.90	940	4.90	2,090	5.90	3,920	6.90	6,280	7.90	8,990
4.00	1,030	5.00	2,250	6.00	4,120	7.00	6,540	8.00	9,270
4.10	1,130	5.10	2,420	6.10	4,330	7.10	6,800	8.10	9,550
4.20	1,230	5.20	2,590	6.20	4,550	7.20	7,070	8.20	9,830
4.30	1,330	5.30	2,770	6.30	4,780	7.30	7,340		
4.40	1,440	5.40	2,960	6.40	5,020	7.40	7,610		
4.50	1,550	5.50	3,150	6.50	5,260	7.50	7,880		
4.60	1,670	5.60	3,340	6.60	5,510	7.60	8,150		

NOTE.—The above table is applicable only to open-channel conditions. It is based on 9 discharge measurements made during 1906 and is well defined.

Monthly discharge of Payette River near Horseshoe Bend, Idaho, for 1906.

[Drainage area, 2,240 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
February 13-28	1,230	940	1,090	34,700	0.488	0.29
March	2,680	1,030	1,930	118,000	.859	.99
April	7,480	2,860	4,960	295,000	2.21	2.47
May	9,550	6.020	7,260	446,000	3.24	3.74
June	8,150	5,260	6,500	390,000	2.92	3.26
July	5,260	1,380	2,900	178.000	1.30	1.50
August	1,380	940	1,120	69,200	.502	.58
September	1,030	805	894	53.200	.399	.44
October	940	805	859	52,800	.383	.44
November	5,020	985	2,130	127,000	.952	1.06
The period	....	....	....	1,760,000	....	....

NOTE.—Values are rated as follows: February to August and November, excellent; September and October, good.

MALHEUR RIVER AT M'LAUGHLIN'S BRIDGE, NEAR VALE, OREG.

This station was established December 10, 1904, and was discontinued December 20, 1906. It is located at the new county bridge, known as McLaughlin's bridge, 10 miles above Vale, Oreg. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 129, where are given also references to publications that contain data for previous years.

Discharge measurements of Malheur River at McLaughlin's bridge, near Vale, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 3	R. S. Hall	81	131	3.18	328
April 26	do	153	568	5.11	2,680
November 28[a]	Stevens and McGlashan	45	120	1.71	107

[a] Channel frozen over above and below bridge.

Daily gage height, in feet, of Malheur River at McLaughlin Bridge, near Vale, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.60	3.62	3.55	10.06	4.25	4.00	2.40	1.35	1.25	1.65	1.90	2.35
2	3.60	3.62	3.25	8.28	4.15	3.62	2.30	1.35	1.30	1.65	1.90	2.35
3	3.60	3.62	3.20	7.85	4.10	3.65	2.30	1.30	1.30	1.70	1.95	2.35
4	3.60	3.62	3.15	7.25	4.05	3.60	2.25	1.25	1.40	1.70	1.95	2.35
5	3.60	3.62	3.20	7.80	4.00	3.60	2.25	1.20	1.35	1.70	1.95	2.35
6	3.60	3.62	3.20	7.40	3.95	3.75	2.25	1.20	1.40	1.70	1.95	2.4
7	3.60	3.62	3.30	7.70	3.95	3.70	2.15	1.15	1.40	1.70	1.95	2.4
8	3.60	3.62	3.80	7.92	3.85	3.60	2.15	1.15	1.45	1.70	1.95	2.4
9	3.60	3.62	3.90	8.08	3.75	3.58	2.15	1.15	1.45	1.70	1.95	2.4
10	3.60	3.62	4.20	7.98	3.65	3.55	1.90	1.15	1.45	1.70	1.95	2.3
11	3.60	3.70	4.10	7.40	3.60	3.55	1.90	1.00	1.45	1.70	1.95	2.2
12	3.60	3.70	3.63	6.85	3.60	3.30	1.90	1.00	1.50	1.70	1.95	2.2
13	3.60	3.70	3.50	6.10	3.65	3.30	1.80	1.00	1.50	1.70	2.00	2.2
14	3.60	3.70	3.35	5.90	3.60	3.25	1.75	1.00	1.55	1.65	2.00	2.2
15	3.60	3.70	3.25	5.95	3.55	3.20	1.75	1.00	1.55	1.65	2.00	2.15
16	3.60	3.70	3.25	6.00	3.52	3.20	1.65	1.00	1.55	1.65	2.00	2.15
17	3.60	3.70	3.20	6.15	3.50	3.15	1.65	1.00	1.60	1.70	2.00	2.15
18	3.60	3.70	3.15	6.15	3.45	3.00	1.60	1.00	1.60	1.70	2.00	2.15
19	3.60	3.75	3.15	5.80	3.30	2.90	1.55	1.05	1.60	1.75	2.05	2.15
20	3.60	4.24	3.15	5.38	3.15	2.85	1.52	1.05	1.65	1.75	2.10	......
21	3.60	4.66	3.15	5.44	3.00	2.80	1.52	1.10	1.65	1.75	2.10	......
22	3.60	4.80	3.25	5.44	3.00	2.75	1.42	1.10	1.62	1.80	2.10	......
23	3.60	5.32	3.85	5.38	2.90	2.50	1.50	1.15	1.60	1.80	2.10	......
24	3.60	4.82	5.15	5.30	2.90	2.50	1.42	1.15	1.60	1.80	2.10	......
25	3.60	4.22	7.25	5.22	2.90	2.50	1.50	1.15	1.60	1.80	2.15	......
26	3.60	3.40	7.38	5.09	2.85	2.50	1.42	1.15	1.60	1.80	2.15	......
27	3.60	3.40	7.40	5.04	2.85	2.50	1.42	1.20	1.65	1.80	2.20	......
28	3.60	3.38	7.40	4.72	3.90	2.50	1.42	1.20	1.65	1.80	2.20	......
29	3.60	......	7.30	4.50	4.10	2.50	1.40	1.25	1.65	1.80	2.22	......
30	3.60	......	8.04	4.25	4.70	2.50	1.40	1.25	1.65	1.85	2.30	......
31	3.60	......	9.88	......	4.65	......	1.40	1.25	......	1.90	......	......

NOTE.—The following ice conditions prevailed during 1906: River frozen over January 1 to February 22; gage heights are to the top of ice. On February 22 an ice jam formed at the bridge; this went out February 25. November 13 to 18, slush ice was running in the morning; the gage heights were taken in the afternoon, and were probably not affected. November 19 there was ice along edges and anchor ice in the bottom; this ice went out December 11. December 14 to 19 ice formed at night, but went out in the daytime, and probably did not affect gage heights.

Rating tables for Malheur River at McLaughlin's Bridge, near Vale, Oreg.

JANUARY 1 TO MARCH 31, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
3.00	270	3.80	755	4.60	1,380	5.40	2,125	6.40	3,610
3.10	320	3.90	825	4.70	1,465	5.50	2,245	6.60	3,970
3.20	375	4.00	900	4.80	1,550	5.60	2,370	6.80	4,350
3.30	430	4.10	975	4.90	1,635	5.70	2,500	7.00	4,750
3.40	490	4.20	1,055	5.00	1,720	5.80	2,640	8.00	7,200
3.50	550	4.30	1,135	5.10	1,810	5.90	2,790	9.00	10,200
3.60	615	4.40	1,215	5.20	1,910	6.00	2,950	10.00	13,250
3.70	685	4.50	1,295	5.30	2,015	6.20	3,270		

APRIL 1 TO DECEMBER 20, 1906.[b]

1.00	5	1.90	215	2.80	630	3.70	1,245	5.20	2,810
1.10	20	2.00	250	2.90	690	3.80	1,325	5.40	3,090
1.20	37	2.10	290	3.00	750	3.90	1,410	5.60	3,380
1.30	56	2.20	330	3.10	815	4.00	1,500	5.80	3,680
1.40	77	2.30	375	3.20	880	4.20	1,690	6.00	4,000
1.50	100	2.40	420	3.30	950	4.40	1,890	7.00	5,900
1.60	125	2.50	470	3.40	1,020	4.60	2,090	8.20	8,150
1.70	155	2.60	520	3.50	1,090	4.80	2,310	9.30	10,650
1.80	185	2.70	575	3.60	1,165	5.00	2,550	10.40	13,250

[a] This table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905-6, and is well defined below gage heights 5 feet. The table has been extended by subtracting the discharge of Bully Creek for April 1 from the discharge at Vale.

[b] This table is applicable only for open-channel conditions. It is based on 1 discharge measurement made during 1906 and on the form of the previous curve, and is not well defined.

Monthly discharge of Malheur River at McLaughlin Bridge, near Vale, Oreg., for 1906.

[Drainage area, 4,150 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
March	12,900	348	2,000	123,000	0.482	0.56
April	13,400	1,740	5,100	303,000	1.23	1.37
May	2,200	660	1,220	75,000	.294	.34
June	1,500	470	851	50,600	.205	.23
July	420	77	190	11,700	.046	.05
August	66	5	27.4	1,680	.0066	.01
September	140	46	106	6,310	.026	.03
October	215	140	165	10,100	.040	.05
November 1-18	250	215	236	8,430	.057	.04
December 11-19	330	310	319	5,690	.077	.03
The period				611,000		

NOTE.—Values are rated as follows: March to June, fair; July to December, approximate.

MALHEUR RIVER AT VALE, OREG.

This station was established May 20, 1903, at the steel highway bridge one-eighth mile southeast of Vale, Oreg., where a station has been maintained at intervals since 1890. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 126, where are given also references to publications that contain data for previous years.

Discharge measurements of Malheur River at Vale, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
January 29	R. S. Hall	102	175	4.45	212
February 15	do	103	174	4.42	197
February 16	do	104	185	4.49	228
March 2	do	122	230	4.93	432
March 24	do	149	599	6.83	1,990
March 25	do	165	986	9.30	5,300
March 29	do	162	1,010	9.54	5,310
April 9	do	165	1,220	10.82	7,190
April 24	do	146	792	7.58	2,840
April 26	do	144	746	7.40	2,670
May 4	do	127	474	6.12	1,250
June 14	do	117	292	5.14	591

Daily gage height, in feet, of Malheur River at Vale, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.39	4.37	5.23	14.34	6.36	6.36	4.30	3.44	3.40	3.68	3.90	4.01
2	4.16	4.35	4.95	11.55	6.26	5.88	4.26	3.40	3.40	3.68	3.92	4.01
3	4.14	4.31	4.78	9.82	6.20	5.61	4.18	3.40	3.41	3.71	3.93	3.98
4	4.40	4.30	4.75	9.52	6.12	5.50	4.14	3.36	3.42	3.72	3.94	3.96
5	4.48	4.31	4.74	9.50	6.02	5.58	4.12	3.33	3.44	3.73	3.98	3.97
6	4.34	4.66	4.84	9.88	5.95	5.88	4.10	3.32	3.51	3.72	3.99	3.98
7	4.49	4.50	4.87	10.51	5.89	5.76	4.03	3.29	3.48	3.74	4.02	4.02
8	4.24	4.32	5.36	10.62	5.76	5.85	3.96	3.29	3.50	3.74	4.02	4.12
9	4.16	4.43	5.80	10.86	5.64	5.75	3.94	3.28	3.51	3.73	4.04	4.22
10	4.18	4.27	6.10	10.54	5.56	5.57	3.90	3.26	3.49	3.72	4.08	4.21
11	4.19	4.27	6.35	9.86	5.51	5.46	3.82	3.26	3.50	3.73	4.04	4.22
12	4.20	4.28	6.07	8.93	5.61	5.38	3.76	3.30	3.51	3.74	4.04	4.21
13	4.20	4.31	5.56	8.52	5.62	5.24	3.72	3.25	3.50	3.74	4.03	4.23
14	4.22	4.36	5.18	8.30	5.52	5.18	3.66	3.24	3.50	3.70	4.03	4.22
15	4.28	4.41	5.34	8.44	5.40	5.10	3.62	3.25	3.54	3.72	4.05	4.24
16	4.20	4.49	5.27	8.49	5.38	5.04	3.55	3.25	3.58	3.73	4.06	4.20
17	4.38	4.52	4.68	8.62	5.32	4.98	3.50	3.25	3.58	3.74	4.06	4.15
18	4.24	4.52	4.55	8.54	5.26	4.87	3.50	3.24	3.59	3.74	4.05	4.17
19	4.25	4.54	4.56	8.23	5.16	4.87	3.51	3.21	3.64	3.75	4.04	4.22
20	4.38	4.80	4.76	7.90	5.04	4.75	3.49	3.20	3.63	3.77	4.11	4.20
21	4.54	5.28	4.76	7.82	4.98	4.68	3.48	3.20	3.64	3.77	4.12	4.17
22	4.36	5.23	4.80	7.79	4.90	4.60	3.34	3.20	3.66	3.81	4.07	4.24
23	4.36	5.51	5.09	7.75	4.83	4.53	3.37	3.18	3.64	3.88	4.00	4.21
24	4.34	5.21	6.98	7.58	4.78	4.44	3.20	3.20	3.64	3.90	3.92	4.22
25	4.33	5.22	9.36	7.47	4.72	4.38	3.38	3.22	3.64	3.92	3.88	4.22
26	4.65	4.90	9.48	7.38	4.68	4.38	3.34	3.28	3.63	3.94	3.92	4.22
27	4.42	4.82	9.53	7.22	4.64	4.31	3.39	3.30	3.66	3.91	4.00	4.26
28	4.46	4.90	9.82	6.96	4.80	4.27	3.50	3.31	3.65	3.90	4.16	4.48
29	4.47	......	9.45	6.60	5.16	4.22	3.50	3.34	3.64	3.90	4.12	4.69
30	4.42	......	10.28	6.44	6.80	4.32	3.50	3.31	3.65	3.89	4.03	4.58
31	4.35	......	12.75	......	6.93	......	3.50	3.39	......	3.90	......	4.50

NOTE.—River frozen two-thirds across November 22. Ice conditions until December 20. Ice attained a maximum thickness of 10 inches.

Rating table for Malheur River at Vale, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
3.20	5	4.40	195	5.50	810	6.70	1,840	8.80	4,330
3.30	9	4.50	235	5.60	880	6.80	1,940	9.00	4,600
3.40	14	4.60	280	5.70	955	6.90	2,045	9.20	4,870
3.50	21	4.70	325	5.80	1,030	7.00	2,150	9.40	5,150
3.60	29	4.80	375	5.90	1,110	7.20	2,370	9.60	5,430
3.70	39	4.90	430	6.00	1,190	7.40	2,595	9.80	5,710
3.80	52	5.00	490	6.10	1,275	7.60	2,825	10.00	6,000
3.90	67	5.10	550	6.20	1,360	7.80	3,060	11.00	7,470
4.00	85	5.20	610	6.30	1,450	8.00	3,300	12.00	8,970
4.10	105			6.40	1,545	8.20	3,550	13.00	10,570
4.20	130	5.30	675	6.50	1,640	8.40	3,810	14.00	12,220
4.30	160	5.40	740	6.60	1,740	8.60	4,070		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 12 discharge measurements made during 1906 and is well defined between gage heights 4.4 feet and 11.0 feet.

Monthly discharge of Malheur River at Vale, Oreg., for 1906.

[Drainage area, 4,860 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	302	115	174	10,700	0.036	0.04
February	817	151	311	17,300	.064	.07
March	10,200	258	1,920	118,000	.395	.46
April	12,800	1,580	4,550	271,000	.936	1.04
May	2,080	298	862	53,000	.177	.20
June	1,510	136	589	35,000	.121	.14
July	160	5	49.7	3,060	.010	.01
August	17	4	8.6	529	.0018	.002
September	35	14	25.7	1,530	.0053	.01
October	74	37	50.5	3,110	.010	.01
November	120	64	89.3	5,310	.018	.02
December	320	78	138	8,480	.028	.03
The year	12,800	4	731	527,000	.150	2.03

NOTE.—Values are rated as follows: January, November, and December, good; February to June, excellent; July, September, and October, fair; August, approximate.

MIDDLE FORK OF MALHEUR RIVER AT RIVERSIDE, OREG.

This station was established January 24, 1906, and was discontinued December 31, 1906, on account of the expense of maintenance. It was located one-half mile above Riverside post-office, and 200 feet above the mouth of South Fork.

The channel is straight; the banks are high and steep. The bed is of gravel and liable to change. There is one channel at all stages.

Discharge measurements were made from a cable.

A chain gage, which was read by J. C. Bloylock, was installed May 8, 1906; length of chain, 15.12 feet. Gage heights previous to this were reduced to the same datum. The bench mark is the highest point of a rock on the left bank near the cable supports, marked B. M.; elevation, 19.41 feet above the gage datum.

The following measurement was made May 9, 1906:

Width, 86 feet; area, 156 feet; gage height, 2.18 feet; discharge, 495 second-feet.

Daily gage height, in feet, of Middle Fork of Malheur River at Riverside, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	1.9	....	6.75	2.2	2.2	1.4	0.6	0.6	0.9	0.9	1.2
2	....	1.9	....	....	2.2	2.1	1.4	.6	.6	.9	1.1	1.2
3	1.9	1.6	....	....	2.2	2.1	1.4	.6	.6	.9	1.1	1.3
4	1.9	1.6	....	6.35	2.2	2.2	1.3	.5	.6	.9	1.1	1.2
5	1.9	1.7	....	....	2.2	2.3	1.2	.5	.6	.9	1.1	1.3
6	1.9	1.8	....	....	2.2	2.2	1.2	.5	.6	.9	1.1	1.2
7	1.9	1.8	....	....	2.2	2.2	1.1	.5	.6	.9	1.1	1.2
8	1.9	1.7	....	6.35	2.1	2.1	1.1	.5	.6	.9	1.1	1.2
9	1.9	1.7	....	6.35	2.2	2.1	1.1	.5	.6	.9	1.1	1.2
10	1.9	1.8	2.0	6.35	2.2	2.1	1.1	.5	.6	1.0	1.1	1.2
11	2.0	1.8	1.9	6.35	2.2	2.1	1.0	.5	.6	1.0	1.1	1.2
12	2.1	1.9	1.8	....	2.1	2.0	1.0	.5	.6	1.0	1.1	1.2
13	2.1	1.9	1.7	....	2.2	2.0	1.0	.5	.6	1.2	1.1	1.2
14	2.1	1.8	1.6	....	2.1	1.9	1.0	.5	.7	1.2	1.1	1.1
15	2.1	1.85	....	....	2.1	1.9	.9	.5	.8	.9	1.1	1.2
16	2.1	1.9	....	....	2.1	1.9	.9	.55	.7	.9	1.1	1.2
17	2.1	1.7	....	....	2.0	1.8	1.0	.5	.7	1.0	1.2	1.2
18	2.2	1.7	....	....	2.0	1.8	1.0	.5	.7	1.0	1.2	1.2
19	2.3	1.7	....	....	1.9	1.7	.9	.5	.7	1.0	1.2	1.2
20	2.3	1.6	....	3.3	1.8	1.7	.9	.5	.7	1.0	1.2	1.2
21	2.4	1.7	....	3.5	1.8	1.6	.9	.5	.7	1.0	1.1	1.2
22	2.0	1.6	1.8	3.4	1.7	1.6	.9	.5	.8	1.0	1.1	1.2
23	....	1.3	2.1	3.4	1.7	1.6	.9	.5	.8	1.0	1.4	1.2
24	2.0	1.1	3.75	3.0	1.7	1.5	.9	.5	.8	1.0	1.5	1.2
25	2.0	1.1	4.1	2.9	1.7	1.4	.8	.5	.8	1.0	1.4	1.3
26	2.0	....	3.8	2.9	1.6	1.4	.8	.5	.8	1.0	1.4	1.7
27	2.1	....	4.15	2.7	1.8	1.6	.8	.5	.8	1.0	1.3	1.8
28	2.1	....	4.2	2.6	2.1	1.5	.8	.5	.9	1.0	1.2	1.6
29	2.0	....	4.2	2.4	2.5	1.4	.7	.6	.9	1.0	1.2	1.5
30	2.0	....	6.75	2.2	2.8	1.5	.7	.6	.9	1.0	1.2	1.5
31	1.9	....	....	....	2.5	....	.7	.6	....	.9	....	1.3

BULLY CREEK ABOVE VALE, OREG.

This station was established January 27, 1905. It is near the location of the original station on Bully Creek, one-fourth mile below Warm Springs stage station, 15 miles above Vale, Oreg. To replace the former bench mark, which had been destroyed, a new one was established May 6, 1906, as follows: A small shoulder cut in rock on upper side of road 6.2 feet upstream from gage; elevation, 6.82 feet above gage datum. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 137, where are given also references to publications that contain data for previous years.

Discharge measurements of Bully Creek above Vale, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
January 28	R. S. Hall	13	6.7	2.03	7.8
March 26	do	77	128	3.98	579
March 27	do	78	176	4.60	1,100
March 28	do	79	151	4.19	826
March 29	do	79	172	4.58	1,010
April 10	do	78	123	3.88	704
April 11	do	68	115	3.70	567
May 5	do	39	43	2.00	52
June 15	do	33	35	1.70	20

Daily gage height, in feet, of Bully Creek above Vale, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.18	2.18	2.14	5.00	2.50	2.18	1.46	1.30	1.30	1.30	1.30	1.50
2	2.18	2.20	2.14	4.20	2.40	2.12	1.50	1.30	1.30	1.30	1.30	1.50
3	2.16	2.24	2.16	4.00	2.30	2.12	1.50	1.30	1.30	1.30	1.30	1.50
4	2.15	2.26	2.18	3.70	2.20	2.14	1.50	1.30	1.30	1.30	1.30	1.50
5	2.12	2.28	2.20	4.20	2.00	2.18	1.50	1.30	1.30	1.30	1.30	1.52
6	2.12	2.30	2.20	4.50	2.00	2.18	1.50	1.30	1.30	1.30	1.30	1.52
7	2.12	2.26	2.30	4.30	1.96	2.18	2.00	1.30	1.30	1.30	1.32	1.52
8	2.14	2.20	2.36	4.00	1.90	2.10	1.80	1.30	1.30	1.30	1.32	1.54
9	2.14	2.10	2.65	4.30	1.80	2.00	1.70	1.30	1.30	1.30	1.34	1.54
10	2.16	2.08	2.80	3.80	1.76	1.90	1.60	1.30	1.30	1.30	1.34	1.56
11	2.16	2.00	2.60	3.60	2.10	1.86	1.52	1.30	1.30	1.30	1.36	1.56
12	2.16	2.00	2.60	3.50	2.18	1.84	1.50	1.30	1.30	1.30	1.40	1.56
13	2.16	2.00	2.60	3.30	2.18	1.80	1.44	1.30	1.30	1.30	1.44	1.54
14	2.16	2.08	2.58	3.30	2.10	1.70	1.40	1.30	1.30	1.30	1.46	1.54
15	2.14	2.10	2.54	3.20	2.00	1.60	1.40	1.30	1.30	1.30	1.46	1.54
16	2.14	2.10	2.40	3.20	2.00	1.64	1.40	1.30	1.30	1.30	1.48	1.52
17	2.12	2.10	2.40	3.10	1.90	1.70	1.40	1.30	1.30	1.30	1.48	1.52
18	2.12	2.10	2.40	3.10	1.90	1.70	1.40	1.30	1.30	1.30	1.48	1.54
19	2.10	2.10	2.50	3.00	1.80	1.70	1.40	1.30	1.30	1.30	1.50	1.54
20	2.08	2.10	2.50	3.00	1.80	1.68	1.40	1.30	1.30	1.30	1.50	1.54
21	2.06	2.10	2.54	3.00	1.80	1.68	1.40	1.30	1.30	1.30	1.50	1.56
22	2.08	2.10	2.80	3.00	1.78	1.66	1.40	1.30	1.30	1.30	1.50	1.56
23	2.08	2.10	3.00	2.80	1.78	1.64	1.40	1.30	1.30	1.30	1.50	1.56
24	2.10	2.10	4.30	2.80	1.74	1.64	1.38	1.30	1.30	1.30	1.50	1.56
25	2.10	2.10	4.10	2.80	1.74	1.60	1.36	1.30	1.30	1.30	1.50	1.56
26	2.10	2.10	4.10	2.60	1.72	1.60	1.34	1.30	1.30	1.30	1.50	1.56
27	2.10	2.12	4.50	2.60	1.72	1.58	1.30	1.30	1.30	1.30	1.50	1.56
28	2.12	2.10	4.30	2.60	1.72	1.58	1.30	1.30	1.30	1.30	1.50	1.56
29	2.12	....	4.30	2.60	1.80	1.56	1.30	1.30	1.30	1.30	1.50	1.56
30	2.14	....	4.90	2.50	2.20	1.50	1.30	1.30	1.30	1.30	1.50	1.54
31	2.16	....	6.10	....	2.20	....	....	1.30	....	1.30	....	1.52

NOTE.—Creek was frozen December 12 to 31; discharges not corrected.

Rating tables for Bully Creek above Vale, Oreg.

JANUARY 1 TO MARCH 31, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.60	0.0	2.40	42	3.20	238	4.00	620	4.80	1,195
1.70	.3	2.50	56	3.30	274	4.10	680	4.90	1,275
1.80	2	2.60	74	3.40	313	4.20	745	5.00	1,360
1.90	6	2.70	96	3.50	355	4.30	815	5.20	1,540
2.00	11	2.80	120	3.60	400	4.40	885	5.40	1,750
2.10	17	2.90	146	3.70	450	4.50	960	5.60	1,980
2.20	24	3.00	174	3.80	505	4.60	1,035	5.80	2,230
2.30	32	3.10	205	3.90	560	4.70	1,115	6.00	2,500

APRIL 1 TO DECEMBER 31, 1906.[b]

1.30	3	2.00	50	2.70	190	3.40	425	4.20	845
1.40	4	2.10	65	2.80	215	3.50	470	4.40	975
1.50	7	2.20	80	2.90	245	3.60	515	4.60	1,110
1.60	12	2.30	100	3.00	275	3.70	565	4.80	1,250
1.70	19	2.40	120	3.10	310	3.80	615	5.00	1,400
1.80	28	2.50	140	3.20	345	3.90	670		
1.90	38	2.60	165	3.30	385	4.00	725		

[a] This table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905-6 and is not well defined.

[b] This table is applicable only for open-channel conditions. It is based on 4 discharge measurements made during 1906 and is fairly well defined.

Monthly discharge of Bully Creek above Vale, Oreg., for 1906.

[Drainage area, 650 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	23	15	18.9	1,160	0.029	0.03
February	32	11	19.2	1,070	.030	.03
March	2,640	20	324	19,900	.498	.57
April	1,400	140	473.0	28,100	.728	.81
May	140	21	50.6	3,110	.078	.09
June	77	7	33.7	2,010	.052	.06
July	50	3	7.61	468	.012	.01
August	3	3	3.0	184	.0046	.01
September	3	3	3.0	179	.0046	.01
October	3	3	3.0	184	.0046	.01
November	7	3	5.23	311	.0080	.01
December	10	7	8.94	560	.014	.02
The year	2,640	3	79.2	57,200	.122	1.66

NOTE.—Values are rated as follows: January to March and July to December, approximate; April to June, good.

BULLY CREEK AT VALE, OREG.

This station was discontinued as a permanent gaging station on December 31, 1905. The conditions and the bench marks are described in Water-Supply Paper No. 178, page 140, where are given also references to publications that contain data for previous years.

A number of measurements were made during 1906, as follows:

Discharge measurements of Bully Creek at Vale, Oreg., in 1906.

Date.	Width.	Area of section.	Gage height.	Discharge.	Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
January 29	15	6.7	3.22	8.5	March 24	45	97	5.52	435
February 15	14	8.3	3.30	11	November 28[a]				3
March 3	14	10	3.36	16					

[a] Estimated at low water; frozen.

WILLOW CREEK NEAR MALHEUR, OREG.

This station was established November 4, 1904, and was discontinued August 15, 1906. It is located at Beer's ranch, about 5 miles from Malheur, on the road to Huntington, Oreg. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 141, where are given also references to publications that contain data for previous years.

The following measurement was made April 5, 1906:

Width, 36 feet; area, 79 square feet; gage height, 4.75 feet; discharge, 355 second-feet.

Daily gage height, in feet, of Willow Creek near Malheur, Oreg., for 1906.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Day.	Mar.	Apr.	May.	June.	July.	Aug.
1	......	5.0	1.9	1.9	1.0	0.2	17	......	2.9	0.8	1.5	......	......
2	......	4.0	1.9	1.8	1.0	......	18	......	2.9	.8	1.25	......	......
3	......	3.9	1.8	1.8	1.0	......	19	......	2.7	.8	1.0	......	......
4	......	5.0	1.5	1.7	......	.2	20	......	2.8	1.3	.9	0.4	......
5	......	5.1	1.3	1.7	.7	.2	21	......	2.7	1.4	.95	.4	......
6	......	5.1	1.3	1.8	.7	.2	22	......	2.6	1.4	.5	.4	......
7	......	5.1	1.2	1.9	.7	.2	23	1.3	2.6	1.8	.6	.4	......
8	......	4.7	1.2	1.9	.7	.2	24	3.8	2.5	1.8	.5	......	......
9	......	4.3	1.2	1.9	.7	.2	25	2.5	2.5	1.9	.5	......	......
10	......	4.0	1.2	1.3	.7	.2	26	2.5	2.5	1.9	.8	......	......
11	......	3.7	1.0	1.4	.65	......	27	3.0	2.5	1.9	.9	.4	......
12	......	3.3	1.0	......	.65	......	28	3.0	2.4	1.9	.9	.3	......
13	......	3.0	1.0	......	.65	.2	29	3.5	2.3	1.9	.8	.3	......
14	......	2.9	.9	1.3	.8	.2	30	4.1	2.1	1.9	1.0	......	......
15	......	2.9	.9	1.3	.7	......	31	4.7	......	1.9	......	......	......
16	......	2.9	.9	1.3	.55	......							

Rating table for Willow Creek near Malheur, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.20	0	1.10	16	2.00	64	2.90	137	3.80	235
.30	.5	1.20	20	2.10	71	3.00	147	3.90	247
.40	1.2	1.30	24	2.20	78	3.10	157	4.00	259
.50	2.2	1.40	29	2.30	86	3.20	167	4.20	283
.60	3.5	1.50	34	2.40	94	3.30	178	4.40	309
.70	5.0	1.60	39	2.50	102	3.40	189	4.60	335
.80	7.0	1.70	45	2.60	110	3.50	200	4.80	361
.90	9.5	1.80	51	2.70	119	3.60	211	5.00	388
1.00	12.5	1.90	57	2.80	128	3.70	223		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905–6 and is fairly well defined below gage height 2 feet.

Monthly discharge of Willow Creek near Malheur, Oreg., for 1906.

[Drainage area, 259 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
March 23-31	348	24	175	3,120	0.676	0.23
April	402	71	196	11,700	.757	.84
May	57	7	32.2	1,980	.124	.14
June	57	2.2	26.5	1,580	.102	.11
July	12.5	0	3.90	240	.015	.02
August 1-14	0	0	0	0	0	0
The period				18,600		

NOTE.—Values are rated as good.

WILLOW CREEK NEAR DELL, OREG.

This station was established May 12, 1904, and was discontinued July 16, 1906, on account of unfavorable conditions. It is located at a bridge at Cole's ranch near Dell, Oreg., 28 miles above Vale. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 143, where are given also references to publications that contain data for previous years.

Discharge measurements of Willow Creek near Dell, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 5[a]	R. S. Hall	8.7	6.1	2.09	10
March 27	do	63	173	5.80	371
March 27	do	62	132	5.00	261
March 28	do	54	91	4.53	175
April 25	do	45	57	4.17	108
June 15	do	46	24	3.11	36

[a] Measured by wading.

Daily gage height, in feet, of Willow Creek near Dell, Oreg., for 1906.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Day.	Feb.	Mar.	Apr.	May.	June.	July.
1		2.2	6.75	3.4	3.4	2.7	17		3.0	4.5	3.0	3.1	2.5
2		2.2	6.5	3.4	3.6	2.7	18		3.1	4.4	2.6	3.0	2.5
3		2.3	5.75	3.2	4.0	2.75	19		2.9	4.4	2.75	3.0	
4		2.2	5.9	3.3	4.0	2.5	20		3.1	4.4	2.6	3.0	
5		2.1	6.4	3.1	3.7	2.6	21	2.1	3.0	4.5	2.9	2.9	
6		2.1	6.1	3.0	3.7	2.6	22	2.15	2.6	4.6	3.0	2.9	
7		2.2	6.0	2.9	3.6	2.6	23	2.2	3.1	4.4	3.6	2.8	
8		2.6	6.1	3.1	3.5	2.5	24	2.2	5.8	4.5	3.7	2.6	
9		2.8	6.0	3.0	3.6	2.6	25	2.2	5.6	4.5	4.0	2.5	
10		2.7	5.9	3.2	3.6	2.5	26	2.1	5.2	4.0	4.1	3.1	
11		2.5	5.6	4.0	3.7	2.6	27	2.2	6.15	4.2	4.0	2.8	
12		2.6	5.4	4.2	3.5	2.6	28	2.1	5.6	4.0	4.1	2.8	
13		2.4	5.5	4.2	3.4	2.6	29		6.0	3.6	4.0	2.75	
14		2.1	5.4	4.2	3.3	2.5	30		5.5	3.5	3.4	2.8	
15		2.4	5.1	3.0	3.2	2.6	31		6.8		3.7		
16		3.0	4.6	3.0	3.15	2.5							

Rating table for Willow Creek near Dell, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.10	7	2.90	32	3.70	79	4.50	156	5.60	345
2.20	9	3.00	37	3.80	87	4.60	168	5.80	395
2.30	11	3.10	42	3.90	95	4.70	181	6.00	445
2.40	14	3.20	47	4.00	104	4.80	195	6.20	500
2.50	17	3.30	53	4.10	113	4.90	210	6.40	560
2.60	20	3.40	59	4.20	123	5.00	225	6.60	620
2.70	24	3.50	65	4.30	133	5.20	260	6.80	680
2.80	28	3.60	72	4.40	144	5.40	300		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 6 discharge measurements made during 1906, and is fairly well defined.

Monthly discharge of Willow Creek near Dell, Oreg., for 1906.

[Drainage area, 455 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
February 21-28	9	7	8.12	129	0.018	0.01
March	680	7	122	7,500	.268	.31
April	665	65	279	16,600	.613	.68
May	123	20	64.5	3,970	.142	.16
June	104	17	52.0	3,090	.114	.13
July 1-18	26	17	19.6	700	.043	.03
The period				32,000		

NOTE.—Values are rated as fair.

POWDER RIVER AT SALISBURY, OREG.[a]

This station was established December 20, 1903. It is located 10 miles above Baker City, Oreg., and one-fourth mile below Salisbury, a station on the Sumpter Valley Railway. The station is above all important diversions and above the point where the river enters the valley which surrounds Baker City. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 148, where are given also references to publications that contain data for previous years.

Discharge measurements of Powder River at Salisbury, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 9 [a]	R. S. Hall	27	24	2.25	45
March 9 [a]	do	24	23	2.28	48
April 14	do	40	88	3.80	368
April 23	do	43	119	4.55	655
May 14	do	40	79	3.60	321
June 12	do	41	74	3.42	297
November 30 [b]	Stevens and McGlashan	35	32	2.38	25

[a] Slush ice running.
[b] Ice measurement; 15 feet of open channel.

Daily gage height, in feet, of Powder River at Salisbury, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.1	2.05	2.15	4.05	4.15	3.35	2.65	2.0	1.8	1.8	1.95	2.5
2	2.1	2.05	2.15	4.2	4.05	3.25	2.55	2.05	1.75	1.75	2.0	2.35
3	2.05	2.1	2.15	3.55	4.15	3.3	2.6	1.85	1.75	1.7	2.1	2.35
4	2.05	2.1	2.15	3.65	4.25	3.4	2.45	1.85	1.75	1.75	2.15	2.45
5	2.05	2.1	2.15	4.3	4.15	3.5	2.4	1.8	1.75	1.8	2.25	2.45
6	2.05	2.15	2.15	4.95	3.75	3.5	2.35	1.9	1.7	1.75	2.25	2.45
7	2.05	2.15	2.15	5.0	4.05	3.4	2.35	1.85	1.75	1.8	2.2	2.5
8	2.05	2.15	2.2	4.5	4.05	3.4	2.35	1.9	1.75	1.8	2.3	2.5
9	2.1	2.2	2.2	4.25	4.05	3.3	2.3	1.85	1.8	1.7	2.25	2.45
10	2.1	2.2	2.25	4.1	3.85	3.4	2.25	1.8	1.7	1.75	2.2	2.45
11	2.1	2.2	2.15	4.2	3.7	3.35	2.25	1.85	1.8	1.75	2.25	2.55
12	2.1	2.2	2.1	3.95	3.7	3.45	2.25	1.85	1.85	1.75	2.35	2.45
13	2.1	2.2	2.1	3.9	3.65	3.4	2.3	1.75	1.75	1.8	2.35	2.45
14	2.05	2.25	2.2	4.05	3.55	3.35	2.25	1.7	1.8	1.75	2.25	2.55
15	2.05	2.25	2.25	4.15	3.35	3.25	2.3	1.75	1.75	1.75	2.15	2.5
16	2.05	2.3	2.25	4.25	3.4	3.35	2.25	1.7	1.75	1.85	2.05	2.65
17	2.0	2.35	2.2	4.05	3.15	3.35	2.2	1.65	1.75	1.85	2.05	2.65
18	2.0	2.35	2.25	4.15	3.05	3.25	2.1	1.65	1.75	1.8	2.05	2.65
19	2.1	2.35	2.35	3.95	3.05	3.25	2.1	1.65	1.75	1.7	1.95	2.45
20	2.15	2.4	2.45	4.05	3.15	3.05	2.05	1.75	1.75	1.8	2.10	2.3
21	2.15	2.45	2.4	4.05	3.15	3.15	2.1	1.8	1.7	1.8	2.15	2.35
22	2.15	2.45	2.45	4.7	3.15	3.1	2.05	1.75	1.75	1.8	2.25	2.45
23	2.1	2.45	2.45	4.55	3.15	3.05	2.1	1.85	1.75	1.8	2.3	2.45
24	2.1	2.4	2.65	4.45	3.05	2.95	2.05	1.85	1.75	1.9	2.4	2.5
25	2.1	2.25	3.0	4.25	3.05	3.1	2.0	1.75	1.7	1.95	2.3	2.6
26	2.1	2.2	3.15	4.1	3.15	3.15	2.05	1.75	1.75	1.95	2.3	2.65
27	2.1	2.1	3.5	3.6	3.1	3.05	2.05	1.7	1.75	1.95	2.3	2.65
28	2.15	2.15	3.5	3.55	3.25	2.95	2.05	1.8	1.8	1.9	2.25	2.55
29	2.15	....	3.6	3.45	3.15	2.85	2.0	1.75	1.8	1.9	2.3	2.45
30	2.1	....	4.2	3.95	3.15	2.7	1.9	1.75	1.7	1.85	2.4	2.45
31	2.1	....	4.55	....	3.25	....	1.9	1.75	....	1.85	....	2.4

NOTE.—The river was frozen January 1 to about February 24 and November 19 to December 31, The gage heights of this stream vary somewhat during the day on account of placer mining upstream.

[a] Formerly known as Powder River near Baker City.

Rating tables for Powder River at Salisbury, Oreg.

OPEN-CHANNEL CONDITIONS, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.60	4	2.20	38	2.80	120	3.40	267	4.00	469
1.70	7	2.30	48	2.90	140	3.50	299	4.20	537
1.80	11	2.40	60	3.00	161	3.60	333	4.40	605
1.90	16	2.50	72	3.10	184	3.70	367	4.60	673
2.00	22	2.60	86	3.20	209	3.80	401	4.80	741
2.10	30	2.70	102	3.30	237	3.90	435	5.00	810

[a] This table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903-1906, and is well defined between gage heights 1.7 feet and 4.6 feet.

ICE CONDITIONS, 1906.[b]

1.95	9	2.10	15	2.30	23	2.50	32	2.70	42
2.00	11	2.20	19	2.40	27	2.60	37		

[b] This table is applicable only for ice conditions. It is based on 3 discharge measurements made at times of ice obstruction during 1904-1906, and is not well defined.

Monthly discharge of Powder River at Salisbury, Oreg., for 1906.

[Drainage area, 275 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	17	11	14.5	892	0.053	0.06
February	43	13	23.1	1,280	.084	.09
March	656	30	114	7,010	.415	.48
April	810	283	513	30,500	1.87	2.09
May	554	172	312	19,200	1.13	1.30
June	299	102	222	13,200	.807	.90
July	94	16	41.8	2,570	.152	.18
August	26	5	11.1	682	.040	.05
September	13	7	9.2	547	.033	.04
October	19	7	11.6	713	.042	.05
November	54	9	30.5	1,810	.111	.12
December	40	23	31.7	1,950	.115	.13
The year	810	5	111	80,400	.404	5.49

NOTE.—Values are rated as follows: January, February, November, and December, fair; March to October, good.

GRANDE RONDE RIVER AT HILGARD, OREG.

This station was established November 6, 1903. It is located at the county highway bridge one-half mile below the Oregon Railroad and Navigation Company station at Hilgard, Oreg. It is just below the mouth of Five Points Creek, which is the first important tributary above Grande Ronde Valley. There are two dams about 20 miles upstream, used to flood the river during the log-driving season. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 150, where are given also references to publications that contain data for previous years.

Gage heights observed during 1906 are of no value as an index of discharge, on account of obstruction and backwater from log jams.

Discharge measurements of Grande Ronde River at Hilgard, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 10	R. S. Hall	108.5	371	5.18	745
April 3	do	102	378	4.88	1,140
May 16[a]	do	70	370	6.74	657
June 22	do	70	242	3.74	238
December 4[b]	Stevens and McGlashan	70	181	3.02	66

[a] Backwater from log jam. [b] Ice measurements.

GRANDE RONDE RIVER AT ELGIN, OREG.

This station was established November 20, 1903. It is located at the lower end of the Grande Ronde Valley at the county bridge on the road from Elgin to Wallowa, Oreg., and is one-fourth mile east of the railroad station. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 153, where are given also references to publications that contain data for previous years.

Discharge measurements of Grande Ronde River at Elgin, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 18	R. S. Hall	95	367	3.34	1,030
June 29	do	94	334	2.93	666
December 10[a]	Stevens and McGlashan	90	310	2.20	290

[a] Narrow strip of ice on each bank.

Daily gage height, in feet, of Grande Ronde River at Elgin, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.9	2.0	2.55	5.45	4.2	5.75	3.0	1.55	1.5	1.7	......	2.05
2	1.85	1.9	2.5	5.4	4.2	5.75	2.6	1.55	1.5	1.7	1.85	2.05
3	1.9	1.95	2.45	5.2	4.2	5.8	2.6	1.5	1.5	1.7	1.85	2.0
4	1.95	1.95	2.45	5.0	4.15	5.75	2.6	1.55	1.5	1.7	1.9	2.0
5	1.85	1.9	2.45	4.8	4.0	5.7	2.5	1.55	1.5	1.7	2.0	2.0
6	1.9	1.95	2.4	4.7	3.95	5.5	2.5	1.55	1.5	1.7	2.0	2.05
7	1.9	2.0	2.45	4.75	3.95	5.5	2.45	1.55	......	1.7	2.0	2.1
8	1.9	1.95	2.9	4.9	3.8	5.45	2.35	1.55	1.5	1.7	2.05	2.2
9	1.85	1.9	3.1	5.0	3.75	5.3	2.5	1.5	1.5	1.7	2.05	2.2
10	1.9	1.9	3.45	5.1	3.7	5.1	2.35	1.5	1.5	1.7	2.05	2.25
11	1.9	......	3.5	5.0	3.75	4.9	......	1.5	1.5	1.7	......	2.3
12	2.0	1.9	3.25	4.85	3.7	4.3	2.1	1.55	1.55	1.7	......	......
13	1.9	1.9	2.9	4.7	3.7	4.5	2.0	1.5	1.6	1.75	2.05	2.3
14	1.95	1.95	2.65	4.5	3.6	4.3	2.0	1.5	1.65	1.75	2.2	2.25
15	1.95	2.0	2.5	4.7	3.6	4.2	1.9	1.5	1.7	......	2.5	2.1
16	2.0	2.05	2.6	4.5	3.6	4.2	1.9	1.5	1.7	1.75	2.6	2.1
17	2.0	2.2	2.5	4.5	3.6	4.2	1.85	1.5	1.75	1.8	2.6	......
18	2.0	2.65	2.45	4.5	3.45	4.05	1.85	1.5	1.8	1.8	2.5	2.15
19	1.95	2.6	2.45	4.5	3.2	3.85	1.8	1.5	1.8	1.8	2.35	2.25
20	1.95	2.85	2.45	4.5	3.15	3.75	......	1.5	1.8	1.75	2.3	2.7
21	1.9	2.8	2.4	4.5	3.0	3.6	1.7	1.5	1.8	1.8	2.1	3.1
22	1.95	2.8	2.5	4.7	3.0	3.5	1.65	1.5	1.75	1.8	2.0	3.1
23	1.95	2.75	2.8	4.9	3.0	3.3	1.65	1.5	1.75	1.8	2.2	3.3
24	2.0	2.65	3.8	4.8	3.0	3.25	1.65	1.5	1.7	1.8	2.1	3.45
25	2.1	2.65	4.2	4.75	3.0	3.2	1.65	1.5	1.7	1.8	2.1	3.9
26	......	2.6	4.5	4.6	3.0	3.1	......	1.5	1.7	1.8	2.1	4.3
27	2.2	2.7	4.8	4.5	2.9	3.0	1.65	1.5	1.7	......	2.1	4.4
28	2.1	2.65	4.9	......	2.9	3.1	1.65	1.5	1.7	1.8	2.1	4.35
29	2.0	......	......	4.35	3.3	3.0	1.6	1.5	1.75	1.8	1.95	4.0
30	2.0	......	5.1	4.1	4.45	2.9	1.6	1.5	1.75	1.8	2.0	3.85
31	1.95	......	5.45	......	4.7	......	1.6	1.5	......	1.8	......	3.7

NOTE.—There was some ice obstruction during November and December.

Rating table for Grande Ronde River at Elgin, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.50	45	2.20	260	2.90	640	3.60	1,340	4.60	3,020
1.60	67	2.30	305	3.00	710	3.70	1,480	4.80	3,380
1.70	92	2.40	350	3.10	790	3.80	1,630	5.00	3,740
1.80	120	2.50	400	3.20	880	3.90	1,790	5.20	4,100
1.90	150	2.60	455	3.30	980	4.00	1,960	5.40	4,460
2.00	185	2.70	515	3.40	1,090	4.20	2,300	5.60	4,820
2.10	220	2.80	575	3.50	1,210	4.40	2,660	5.80	5,200

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904–1906 and is well defined below gage height 3.5 feet.

Monthly discharge of Grande Ronde River at Elgin, Oreg., for 1906.

[Drainage area, 1,350 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	260	135	172	10,600	0.127	0.15
February	608	150	293	16,300	.217	.23
March	4,550	350	1,230	75,600	.911	1.05
April	4,550	2,130	3,270	195,000	2.42	2.70
May	3,200	640	1,440	88,500	1.07	1.23
June	5,200	640	2,670	159,000	1.98	2.21
July	710	67	220	13,500	.163	.19
August	56	45	47.8	2,940	.035	.04
September	120	45	78.4	4,670	.058	.06
October	120	92	107	6,580	.079	.09
November	455	128	235	14,000	.174	.19
December	2,660	185	756	46,500	.560	.65
The year	5,200	45	877	603,000	.650	8.79

NOTE.—Discharges have been interpolated for days when the gage was not read. November and December have been applied as for open channel. Values are rated as follows: January, February, July, and October to December, fair; March to June, good; August and September, approximate.

GRANDE RONDE RIVER AT ZINDEL, WASH.

This station was established June 30, 1904. It is located at Zindel Ferry, 2 miles above the mouth of the river and 1½ miles below Joseph Creek. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 155, where are given also references to publications that contain data for previous years.

The following measurement was made by floats December 22, 1906:

Width, 224 feet; area, 1,310 square feet; gage height, 5.60 feet; discharge, 8,400 second-feet.

Daily gage height, in feet, of Grande Ronde River at Zindel, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.2	2.45	3.5	6.4	5.1	6.0	3.9	2.2	2.1	2.1	2.35	3.0
2	2.2	2.3	3.3	6.0	5.1	5.8	3.9	2.2	2.1	2.1	2.35	3.0
3	2.2	2.25	3.3	5.8	5.0	5.7	3.8	2.2	2.1	2.1	2.3	3.0
4	2.3	2.3	3.3	5.5	5.1	5.9	3.8	2.2	2.2	2.2	2.3	3.0
5	2.3	2.35	3.5	5.5	5.0	5.8	3.8	2.2	2.2	2.2	2.3	3.0
6	2.3	2.35	3.5	5.7	4.8	5.8	3.8	2.2	2.2	2.2	2.3	2.9
7	2.3	2.35	3.5	5.9	4.7	5.8	3.8	2.2	2.2	2.2	2.6	2.9
8	2.3	2.3	3.5	5.9	4.7	5.7	3.75	2.2	2.2	2.2	3.35	3.0
9	2.3	2.3	3.9	6.0	4.7	5.7	3.6	2.2	2.2	2.2	3.3	3.1
10	2.3	2.25	4.2	5.9	4.9	5.5	3.6	2.2	2.2	2.2	3.1	3.2
11	2.3	2.25	4.1	5.8	5.1	5.5	3.6	2.2	2.1	2.2	3.0	3.2
12	2.3	2.3	3.9	5.2	5.0	5.7	3.55	2.2	2.1	2.2	3.1	3.4
13	2.35	2.3	3.7	5.2	4.8	5.7	3.5	2.4	2.2	2.2	3.4	3.4
14	2.35	2.3	3.2	5.1	4.7	5.2	3.25	2.2	2.2	2.2	6.85	3.1
15	2.2	2.3	3.2	5.2	4.5	4.9	3.0	2.2	2.2	2.2	6.85	3.1
16	2.2	2.5	3.2	5.3	4.2	5.2	3.0	2.2	2.2	2.25	5.8	3.1
17	2.25	2.5	2.8	5.0	4.2	5.0	3.0	2.2	2.1	2.25	5.1	3.0
18	2.25	2.8	3.0	5.3	4.0	4.8	2.9	2.2	2.1	2.25	4.5	3.0
19	2.3	3.9	2.9	5.3	4.0	4.6	2.8	2.2	2.15	2.25	4.1	3.1
20	2.3	3.9	2.9	5.3	4.0	4.4	2.7	2.2	2.15	2.25	3.9	3.3
21	2.3	3.55	2.9	5.5	4.0	4.3	2.7	2.05	2.15	2.25	3.9	5.65
22	2.3	3.7	3.1	6.0	4.0	4.2	2.6	2.0	2.15	2.25	3.6	5.6
23	2.4	3.8	3.1	6.0	3.9	4.1	2.55	2.0	2.15	2.25	3.5	5.1
24	2.4	3.8	3.4	6.0	3.9	4.0	2.55	2.2	2.15	2.25	3.3	5.1
25	2.5	3.6	4.9	5.6	3.9	3.9	2.4	2.2	2.1	2.25	3.3	4.9
26	2.6	3.45	5.2	5.6	3.8	3.9	2.4	2.2	2.1	2.25	3.1	5.8
27	2.55	3.7	5.6	5.6	3.8	3.8	2.4	2.2	2.1	2.3	3.1	5.9
28	2.4	3.5	5.7	5.4	3.8	3.8	2.3	2.2	2.1	2.45	3.0	5.7
29	2.4	....	5.8	5.0	4.1	3.8	2.3	2.1	2.1	2.45	3.0	5.4
30	2.4	....	5.8	5.1	4.8	3.8	2.3	2.1	2.1	2.4	3.0	5.3
31	2.4	....	6.1	....	5.6	....	2.2	2.1	....	2.4	....	5.0

CATHERINE CREEK NEAR UNION, OREG.

This station was established May 15, 1906. It is located in the canyon at the head of a fertile valley 6 miles above Union.

Discharge measurements are made from a highway bridge just below Robbins's sawmill, where there is a dam that affects the flow somewhat.

The gage is read by H. D. Drake, who is paid by the citizens of Union. It is a vertical staff attached to the downstream side of the bridge. The bench mark is the head of a spike driven into the top of the downstream end of log-tying at the end of the bridge; elevation, 7.67 feet above the datum of the gage.

Discharge measurements of Catherine Creek near Union, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 29	R. S. Hall	38	68	3.20	335
May 15	do	38	68	3.30	375
June 24	do	37.5	61	3.10	276
December 1[a]	Stevens and McGlashan	39	51	2.80	54

[a] Channel obstructed by anchor ice.

Daily gage height, in feet, of Catherine Creek near Union, Oreg., for 1906.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	3.5	2.9	2.1	2.1	2.0	2.0	2.5
2	....	3.7	2.8	2.1	2.1	2.0	2.0	2.6
3	....	3.8	2.8	2.1	2.1	2.1	2.1	2.6
4	....	4.0	2.8	2.1	2.0	2.1	2.1	2.8
5	....	3.9	2.8	2.1	2.0	2.1	2.2	2.5
6	....	3.8	2.7	2.1	2.0	2.0	2.1	2.3
7	....	3.7	2.7	2.1	2.0	2.0	2.2	2.3
8	....	3.5	2.7	2.1	2.0	2.0	2.2	2.2
9	....	3.5	2.6	2.1	2.0	2.0	2.2	2.2
10	....	3.5	2.6	2.1	2.0	2.0	2.2	2.2
11	....	3.6	2.6	2.1	2.0	2.0	2.2	2.3
12	....	3.6	2.5	2.1	2.0	2.1	2.2	2.3
13	....	3.5	2.5	2.1	2.1	2.0	3.1	2.2
14	....	3.4	2.5	2.1	2.1	2.0	3.6	2.2
15	3.3	3.3	2.4	2.1	2.1	2.0	3.0	2.2
16	3.2	3.3	2.4	2.1	2.1	2.0	2.7	2.2
17	3.1	3.3	2.4	2.1	2.1	2.0	2.6	2.2
18	3.0	3.3	2.4	2.1	2.1	2.0	2.5	2.2
19	3.0	3.2	2.4	2.1	2.0	2.0	2.7	2.2
20	3.0	3.1	2.3	2.1	2.0	2.0	2.5	2.3
21	3.0	3.1	2.3	2.1	2.0	2.0	2.5	2.3
22	3.0	3.1	2.3	2.1	2.0	2.0	2.4	2.4
23	3.0	3.0	2.3	2.1	2.0	2.0	2.3	2.5
24	3.0	3.0	2.3	2.1	2.0	2.0	2.2	2.6
25	3.0	3.0	2.3	2.1	2.0	2.0	2.3	2.7
26	3.1	3.0	2.3	2.1	2.0	2.1	2.5	3.0
27	3.1	3.1	2.2	2.1	2.0	2.1	2.5	3.0
28	3.0	3.0	2.2	2.1	2.0	2.0	2.4	2.8
29	3.2	2.9	2.2	2.1	2.0	2.1	2.4	2.7
30	3.3	2.8	2.2	2.1	2.0	2.0	2.4	2.7
31	3.4	....	2.2	2.1	....	2.0	....	2.6

NOTE.—Anchor ice formed in the bed of the stream about December 10 and remained until the end of the year.

WALLOWA RIVER AT JOSEPH, OREG.

This station was established November 12, 1903. It is located 500 feet below the outlet of Wallowa Lake, about 1¼ miles above Joseph, Oreg. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 156, where are given also references to publications that contain data for previous years.

Discharge measurements of Wallowa River at Joseph, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 23	R. S. Hall	37.5	64	2.65	247
June 27	do	37.5	75	2.80	335
December 7	Stevens and McGlashan	33	42	2.20	128

Daily gage height, in feet, of Wallowa River at Joseph, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.9	1.9	2.1	2.0	2.4	2.6	2.8	2.9	2.05	1.8	1.95	2.3
2	1.9	1.9	2.1	2.0	2.4	2.6	2.85	2.9	2.0	1.9	......	2.3
3	1.9	1.9	2.05	1.95	2.4	2.65	2.9	2.95	2.0	1.9	2.0	2.3
4	1.95	1.9	2.0	1.95	2.45	2.6	3.0	2.9	2.0	1.9	2.1	2.3
5	1.95	1.9	2.0	1.95	2.5	2.6	3.0	2.85	2.0	1.85	2.05	2.25
6	1.95	1.9	2.0	1.95	2.2	2.6	3.0	2.8	2.0	1.9	2.05	2.2
7	1.95	1.9	1.95	1.95	2.3	2.6	3.0	2.8	2.0	1.9	2.1	2.2
8	1.95	1.9	2.0	1.95	2.35	2.6	3.0	2.75	2.0	1.9	2.1	2.2
9	1.95	1.9	2.0	2.0	2.4	2.6	3.1	2.7	2.0	1.9	2.1	2.2
10	1.9	1.9	2.0	2.0	2.45	2.7	3.15	2.6	2.0	1.9	2.1	2.2
11	1.9	1.9	2.0	2.0	2.5	2.65	3.15	2.5	2.0	1.9	......	2.2
12	1.9	1.9	......	2.0	2.5	2.6	3.0	2.5	2.5	1.9	2.15	2.2
13	1.9	1.9	2.0	2.0	2.4	2.65	3.0	2.5	2.5	1.9	2.2	2.2
14	1.9	1.9	2.0	2.0	2.35	2.7	3.0	2.5	2.1	1.9	2.3	2.2
15	1.9	1.9	2.0	2.0	2.3	2.7	3.0	2.45	2.1	1.9	2.5	2.2
16	2.0	1.9	1.95	2.0	2.3	2.65	3.05	2.4	2.0	1.9	2.6	2.2
17	1.95	1.9	1.95	2.0	2.4	2.55	2.95	2.4	2.0	1.95	2.6	2.2
18	1.95	1.9	1.95	2.0	2.4	2.6	2.8	2.35	2.0	1.95	2.7	2.15
19	1.95	1.95	1.9	2.0	2.4	2.5	2.8	......	2.0	1.95	2.7	2.1
20	1.95	1.9	1.9	2.1	2.4	2.5	2.85	2.3	2.0	1.95	2.65	2.1
21	1.95	1.95	1.95	2.15	2.4	2.6	2.85	2.3	2.0	1.95	2.65	2.2
22	1.9	1.95	......	2.2	2.4	2.6	2.8	2.25	2.0	1.95	2.6	2.2
23	1.95	1.95	1.95	2.3	2.6	2.7	2.75	2.2	2.0	1.95	2.6	2.2
24	1.95	1.95	1.95	2.3	2.7	2.7	2.8	2.25	......	1.95	2.55	2.2
25	1.95	1.95	1.95	2.3	2.5	2.7	2.8	2.2	2.0	1.95	2.55	2.15
26	1.95	1.95	1.95	2.35	2.7	......	2.85	2.15	1.9	1.9	2.5	2.1
27	1.95	2.1	1.95	2.35	2.8	2.8	2.9	2.1	1.8	1.9	2.45	2.1
28	1.95	2.1	1.95	2.4	2.65	2.85	3.0	2.1	1.85	1.95	2.4	2.15
29	1.9	......	1.95	2.4	2.7	2.85	2.95	2.1	1.85	1.95	2.4	2.2
30	1.9	......	1.95	2.4	2.7	2.85	2.9	2.1	1.8	1.9	2.35	2.15
31	1.9	......	2.0	......	2.6	......	2.9	2.1	......	1.95	......	2.15

Note.—The river was not frozen at any time during the year.

Rating table for Wallowa River at Joseph, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.80	26	2.10	77	2.40	170	2.70	299	3.00	464
1.90	35	2.20	104	2.50	209	2.80	350	3.10	527
2.00	54	2.30	135	2.60	252	2.90	405	3.20	597

Note.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905-6 and is well defined between gage heights 2.0 feet and 2.75 feet.

Monthly discharge of Wallowa River at Joseph, Oreg., for 1906.

[Drainage area, 47 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	54	35	40.5	2,490	0.862	0.99
February	77	35	40.2	2,230	.855	.89
March	77	35	50.1	3,080	1.07	1.23
April	170	44	81.9	4,870	1.74	1.94
May	350	104	201	12,400	4.28	4.93
June	377	209	279	16,600	5.94	6.63
July	561	324	426	26,200	9.06	10.44
August	434	77	208	12,800	4.43	5.11
September	209	26	62.1	3,700	1.32	1.47
October	44	26	38.0	2,340	0.809	.93
November	299	44	159	9,460	3.38	3.77
December	135	77	103	6,330	2.19	2.52
The year	561	26	141	102,000	2.99	40.84

Note.—Values are rated as follows: January to March, September, and October, fair; remainder of year, good.

WALLOWA RIVER NEAR WALLOWA, OREG.

This station was established November 14, 1903. It is located at the county bridge, 1½ miles below Wallowa, Oreg., and one-fourth mile below the mouth of Bear Creek. A small irrigation ditch takes water from the river about 300 feet above the bridge on the right bank. During 1906 the gage was read by L. S. Johnson and C. C. Roop. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 159, where are given also references to publications that contain data for previous years.

Discharge measurements of Wallowa River near Wallowa, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 22	R. S. Hall	85	165	2.78	794
June 26	do	85.5	198	3.11	1,120
December 8	Stevens and McGlashan	84	140	2.22	528

Daily gage height, in feet, of Wallowa River near Wallowa, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.7	1.75	1.9	2.7	2.8	3.0	3.0	1.9	1.9	1.7	2.0	2.2
2	1.8	1.7	1.8	2.5	2.9	3.1	3.1	1.9	1.9	1.7	1.9	2.2
3	1.8	1.7	1.9	2.5	3.0	3.1	3.2	1.9	1.9	1.7	2.0	2.1
4	1.75	1.65	1.9	2.4	3.3	3.3	3.2	1.9	1.9	1.7	2.0	2.1
5	1.75	1.7	1.9	2.4	3.0	3.2	3.3	1.8	1.8	1.7	2.1	2.1
6	1.8	1.6	1.9	2.5	3.0	3.1	3.2	1.8	1.8	1.7	2.1	2.1
7	1.7	1.8	1.9	2.6	2.9	3.0	3.2	1.8	1.8	1.7	2.1	2.1
8	1.7	2.0	1.95	2.6	2.9	2.9	3.2	1.8	1.8	1.7	2.6	2.2
9	1.8	2.2	2.0	2.7	3.0	2.9	3.1	1.8	1.9	1.8	2.6	2.2
10	1.8	2.0	2.1	2.7	3.2	3.0	3.0	1.7	1.9	1.8	2.6	2.1
11	1.75	2.1	2.0	2.5	3.4	3.3	2.8	1.7	1.9	1.8	2.7	2.2
12	1.75	1.8	1.9	2.5	3.5	3.8	2.7	1.8	1.9	1.8	2.6	2.2
13	1.8	1.9	1.8	2.4	3.1	3.7	2.7	1.9	1.8	1.8	3.5	2.2
14	1.8	1.8	1.9	2.4	3.1	3.4	2.7	1.9	2.0	1.8	4.8	2.1
15	1.7	1.8	1.9	2.4	3.0	3.4	2.6	1.9	2.0	1.9	4.7	2.0
16	1.75	1.8	1.7	2.6	2.8	3.8	2.6	1.8	1.9	1.9	3.8	2.0
17	1.8	1.8	1.7	2.7	2.7	3.5	2.5	1.8	1.9	2.0	3.3	2.0
18	1.8	1.8	1.8	2.7	2.6	3.2	2.4	1.8	1.9	1.9	3.1	2.0
19	1.8	2.0	1.9	2.6	2.5	3.2	2.4	1.8	1.9	1.9	2.9	2.1
20	1.8	1.9	1.8	2.7	2.6	3.2	2.4	1.8	1.9	1.9	2.9	2.3
21	1.8	2.0	1.9	2.9	2.6	3.2	2.4	1.8	1.8	1.9	2.8	2.3
22	1.8	2.0	1.9	3.1	2.8	3.1	2.1	1.8	1.8	1.9	2.7	2.3
23	1.8	2.0	2.0	3.2	2.7	3.2	2.1	1.8	1.8	1.9	2.6	2.3
24	1.8	1.9	2.2	3.0	2.7	3.1	2.0	1.8	1.8	1.9	2.5	2.3
25	1.8	1.9	2.4	2.9	2.7	3.1	2.0	1.9	1.8	1.9	2.5	2.4
26	1.8	1.9	2.4	2.7	2.9	3.2	1.9	1.8	1.8	1.9	2.4	2.6
27	1.7	1.9	2.6	2.8	2.9	3.4	1.9	1.8	1.8	1.9	2.3	2.5
28	1.75	1.9	2.6	2.8	2.9	3.3	1.9	1.8	1.8	2.1	2.3	2.5
29	1.75	....	2.5	2.8	2.9	3.0	1.9	1.8	1.8	2.1	2.3	2.5
30	1.75	....	2.7	2.8	3.0	2.9	1.9	1.9	....	2.0	2,3	2.4
31	1.75	....	2.7	....	3.0	....	1.9	1.9	....	2.0	....	2.3

Rating tables for Wallowa River near Wallowa, Oreg.

JANUARY 1 TO NOVEMBER 14, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.50	140	2.10	375	2.70	710	3.30	1,290	3.90	1,950
1.60	170	2.20	425	2.80	790	3.40	1,400	4.00	2,070
1.70	205	2.30	475	2.90	880	3.50	1,510	4.20	2,310
1.80	245	2.40	525	3.00	980	3.60	1,620	4.40	2,570
1.90	285	2.50	580	3.10	1,080	3.70	1,730	4.60	2,830
2.00	330	2.60	640	3.20	1,180	3.80	1,840	4.80	3,100

[a] This table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905-6, and is well defined between gage heights 1.7 feet and 3.1 feet.

NOVEMBER 15 TO DECEMBER 31, 1906.[b]

1.50	210	2.10	460	2.70	830	3.30	1,330	3.90	1,950
1.60	245	2.20	515	2.80	900	3.40	1,420	4.00	2,070
1.70	285	2.30	570	2.90	980	3.50	1,520	4.20	2,310
1.80	325	2.40	630	3.00	1,060	3.60	1,620	4.40	2,570
1.90	365	2.50	690	3.10	1,150	3.70	1,730	4.60	2,830
2.00	410	2.60	760	3.20	1,240	3.80	1,840		

[b] This table is applicable only for open-channel conditions. It is based on one discharge measurement made during 1906 and the form of previous curves and is not well defined.

Monthly discharge of Wallowa River near Wallowa, Oreg., for 1906.

[Drainage area, 510 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	245	205	233	14,300	0.457	0.53
February	425	170	275	15,300	.539	.56
March	710	205	363	22,300	.712	.82
April	1,180	525	707	42,100	1.39	1.55
May	1,510	580	912	56,100	1.79	2.06
June	1,840	880	1,210	72,000	2.37	2.64
July	1,290	285	687	42,200	1.35	1.56
August	285	205	255	15,700	.500	0.58
September	330	225	267	15,900	.524	0.58
October	375	205	267	16,400	.524	0.60
November	3,100	285	877	52,200	1.72	1.92
December	760	410	530	32,600	1.04	1.20
The year	3,100	170	549	397,000	1.08	14.60

NOTE.—Values are rated as good.

WALLOWA RIVER NEAR ELGIN, OREG.

This station was established November 18, 1903. It is located at the county highway bridge just below the mouth of Minam River, 12 miles from Elgin, Oreg. The station is in Wallowa Canyon about 9 miles below the lower end of Wallowa Valley. The gage was read during 1906 by Tillie Ransom. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 161, where are given also references to publications that contain data for previous years.

Discharge measurements of Wallowa River near Elgin, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 21	R. S. Hall	194	457	3.60	1,580
June 28	....do	199	570	4.14	2,490
December 9	Stevens and McGlashan	135	264	2.90	777

Daily gage height, in feet, of Wallowa River near Elgin, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.25	2.25	2.6	2.8	....	4.0	3.9	2.5	2.3	2.25	2.45	2.7
2	2.3	2.3	2.5	2.6	....	4.0	4.0	2.5	2.3	2.25	2.4	2.65
3	2.3	2.3	2.5	3.8	....	4.15	4.0	2.45	2.3	....	2.4	2.65
4	2.25	2.3	2.5	3.8	....	4.5	4.1	2.45	2.3	....	2.45	2.6
5	2.2	2.25	2.5	3.3	....	4.3	4.1	2.45	2.3	....	2.5	2.6
6	2.2	2.25	2.5	3.3	....	4.1	4.0	2.45	2.3	2.25	2.45	2.6
7	2.2	2.25	2.55	3.6	....	4.0	4.0	2.4	2.3	2.25	2.55	2.85
8	2.2	2.2	2.65	3.5	....	3.9	4.0	2.35	2.3	2.25	3.3	2.85
9	2.3	2.2	2.8	3.4	....	3.9	3.8	2.35	2.3	2.25	3.1	2.9
10	2.3	2.25	2.9	3.3	....	4.0	3.7	2.35	2.3	2.25	3.1	2.9
11	2.3	2.3	2.8	3.3	....	4.38	3.6	2.35	2.3	2.25	3.2	2.95
12	2.35	2.3	2.65	3.3	....	4.75	3.6	2.35	2.3	2.3	3.1	3.0
13	2.25	2.3	2.45	3.3	....	4.6	3.4	2.35	2.4	2.3	4.5	3.0
14	2.2	2.4	2.5	3.3	....	4.4	3.3	2.35	2.4	2.3	5.52	2.95
15	2.2	2.4	2.55	3.3	....	4.4	3.3	2.35	2.4	2.3	5.45	2.95
16	2.2	2.35	2.65	3.3	....	4.8	3.2	2.35	2.35	2.35	4.4	2.95
17	2.2	2.35	2.6	3.4	....	4.7	3.1	2.35	2.35	2.4	4.1	2.9
18	2.2	2.4	2.3	3.4	....	4.4	3.1	2.35	2.35	2.4	3.7	2.95
19	2.2	2.7	2.45	3.5	....	4.2	3.0	2.3	2.35	2.35	3.5	2.95
20	2.3	2.7	2.45	3.6	3.6	4.15	2.95	2.3	2.35	2.35	3.45	3.4
21	2.2	2.8	2.5	3.8	3.6	4.25	2.9	2.3	2.3	2.35	3.45	3.7
22	2.2	2.8	2.6	3.8	3.75	4.1	2.85	2.3	2.3	2.3	3.35	3.4
23	2.2	2.7	2.6	3.8	3.65	3.9	2.8	2.3	2.3	2.3	3.3	3.35
24	2.3	2.7	2.9	4.2	3.6	3.9	....	2.4	2.3	2.3	3.25	3.3
25	2.3	2.7	3.4	4.2	3.65	4.0	2.7	2.35	2.3	2.3	3.2	3.3
26	2.3	2.7	3.4	4.0	3.95	4.1	2.6	2.35	2.3	2.3	3.2	3.9
27	2.25	2.7	3.7	3.8	3.9	4.4	2.55	2.3	2.3	2.7	3.1	3.6
28	2.3	2.8	3.4	3.6	3.8	4.4	2.55	2.3	2.3	2.55	3.1	3.55
29	2.3	....	3.5	....	3.85	3.9	2.55	2.3	2.3	2.5	3.0	3.5
30	2.3	....	3.65	....	4.0	3.8	2.55	2.3	2.25	2.5	2.9	3.4
31	2.25	....	3.75	....	4.05	....	2.5	2.3	....	2.45	....	3.3

Rating table for Wallowa River near Elgin, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.00	215	2.70	615	3.40	1,330	4.10	2,385	4.80	3,700
2.10	255	2.80	695	3.50	1,470	4.20	2,555	4.90	3,920
2.20	300	2.90	780	3.60	1,610	4.30	2,730	5.00	4,140
2.30	350	3.00	870	3.70	1,755	4.40	2,910	5.20	4,600
2.40	405	3.10	970	3.80	1,905	4.50	3,100	5.40	5,090
2.50	470	3.20	1,080	3.90	2,060	4.60	3,300		
2.60	540	3.30	1,200	4.00	2,220	4.70	3,500		

Note.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903-1906 and is well defined below gage height 4.2 feet.

Monthly discharge of Wallowa River near Elgin, Oreg., for 1906.

[Drainage area, 870 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	378	300	326	20,000	0.375	0.43
February	695	300	453	25,200	.521	.54
March	1,830	350	759	46,700	.872	1.01
April 1-28	2,560	540	1,520	84,400	1.75	1.82
May 20-31	2,300	1,610	1,880	44,700	2.16	.96
June	3,700	1,900	2,600	15,500	2.99	3.34
July	2,380	470	1,280	78,700	1.47	1.70
August	470	350	384	23,600	.441	.51
September	405	325	359	21,400	.413	.46
October	615	325	372	22,900	.428	.49
November	5,420	405	1,420	84,500	1.63	1.82
December	2,060	540	1,010	62,100	1.16	1.34
The period				530,000		

Note.—Values are rated as excellent.

ASOTIN CREEK NEAR ASOTIN, WASH.

This station was established March 25, 1904. It is located at Shellman's ranch, about 8 miles above Asotin, Wash. Gage height observations were discontinued during 1906, as no observer was available. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 167, where are given also references to publications that contain data for previous years.

Discharge measurements of Asotin Creek near Asotin, Wash., in 1904 and 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1904.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 25	W. W. Schlecht	35	31	2.03	113
April 22	W. G. Steward	40	70	3.15	458
July 1	do	30	31	1.79	92
August 12	Hulburt and Moore	26	17	1.52	40
1906.					
December 24	H. McGlashan	36	50	2.30	215

Daily gage height, in feet, of Asotin Creek near Asotin, Wash., for 1906.

Day.	Jan.	Feb.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	1.45	1.55		2.0	1.6	1.4	1.4	1.4	1.5
2	1.45	1.55		2.0	1.6	1.4	1.4	1.4	1.5
3	1.45	1.55		2.0	1.6	1.4	1.4	1.5	1.5
4	1.58	1.55		2.1	1.6	1.4	1.4	1.5	1.5
5	1.55	1.55		2.1	1.5	1.4	1.4	1.5	1.5
6	1.98	1.55		2.1	1.5	1.4	1.4	1.5	1.5
7	1.52	1.55		2.0	1.5	1.4	1.4	1.5	1.5
8	1.45	1.55		1.9	1.5	1.4	1.4	1.5	1.8
9	1.45	1.55		1.9	1.5	1.4	1.4	1.5	1.7
10	1.5	1.55		1.8	1.5	1.4	1.4	1.5	1.6
11	1.5	1.55		1.8	1.5	1.4	1.4	1.5	1.6
12	1.5	1.55		1.8	1.5	1.4	1.4	1.5	1.6
13	1.5	1.55		1.8	1.5	1.4	1.4	1.5	1.8
14	1.5	1.55		1.8	1.5	1.5	1.4	1.5	2.2
15	1.52	1.55		1.8	1.5	1.5	1.4	1.5	2.3
16	1.5	1.55		1.8	1.5	1.5	1.4	1.5	2.4
17	1.5	1.62	1.8	1.8	1.5	1.5	1.4	1.5	2.2
18	1.5		1.8	1.7	1.5	1.5	1.4	1.5	2.0
19	1.5		1.7	1.7	1.5	1.5	1.4	1.5	1.9
20	1.5		1.7	1.7	1.5	1.5	1.4	1.5	1.9
21	1.5		1.7	1.7	1.5	1.5	1.4	1.5	1.8
22	1.5		1.7	1.7	1.5	1.5	1.4	1.5	1.8
23	1.7		1.7	1.7	1.5	1.5	1.4	1.5	1.7
24	1.6		1.7	1.7	1.5	1.5	1.4	1.5	1.7
25	1.55		1.7	1.6	1.5	1.5	1.4	1.5	1.7
26	1.55		1.7	1.6	1.5	1.5	1.4	1.5	1.7
27	1.55		1.7	1.6	1.5	1.5	1.4	1.5	1.7
28	1.55		1.7	1.6	1.5	1.5	1.4	1.5	1.6
29	1.55		1.9	1.6	1.5	1.5	1.4	1.5	1.6
30	1.55		2.1	1.6	1.5	1.5	1.4	1.5	1.6
31	1.55		2.1		1.5	1.4		1.5	

Rating table for Asotin Creek near Asotin, Wash., for 1904–1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.40	29	2.00	126	2.60	277	3.20	502	3.80	829
1.50	40	2.10	147	2.70	309	3.30	549	3.90	894
1.60	54	2.20	169	2.80	343	3.40	599	4.00	962
1.70	70	2.30	193	2.90	379	3.50	652	4.10	1,032
1.80	87	2.40	219	3.00	417	3.60	708	4.20	1,104
1.90	106	2.50	247	3.10	458	3.70	767	4.30	1,179

NOTE.—The above table is applicable only for open-channel conditions. It is based on 5 discharge measurements made during 1904–1906 and is not well defined.

Monthly discharge of Asotin Creek near Asotin, Wash., for 1904–1906.

[Drainage area, 171 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1904.						
March 21-31	193	116	156	3,400	0.912	0.37
April	1,180	198	469	27,900	2.74	3.06
May	417	219	276	17,000	1.61	1.86
June	277	78	159	9,460	.930	1.04
July	116	50	70.8	4,350	.414	.48
August	54	44	47.0	2,890	.275	.32
September	64	44	47.3	2,810	.277	.31
October	85	47	50.5	3,100	.295	.34
November 1-19	47	47	47.0	1,770	.275	.19
The period				72,700		
1905.						
April	96	62	80.3	4,780	0.470	0.52
May	106	78	91.8	5,640	.537	.62
June	283	54	189	11,200	1.11	1.24
July	70	34	43.1	2,650	.252	.29
August	34	34	34.0	2,090	.199	.23
September	62	34	36.2	2,150	.212	.24
October	47	40	40.7	2,500	.238	.28
November	40	34	39.1	2,330	.229	.26
December	47	34	38.9	2,390	.228	.26
The period				35,700		
1906.						
January	122	34	45.5	2,800	0.266	0.31
February 1-17	57	47	47.6	1,600	.278	.18
May 17-31	147	70	85.0	2,530	.497	.28
June	147	54	89.0	5,300	.520	.58
July	54	40	41.8	2,570	.244	.28
August	40	29	35.0	2,150	.205	.24
September	29	29	29.0	1,730	.170	.19
October	40	29	39.3	2,420	.230	.27
November	219	40	82.5	4,910	.482	.54
The period				26,000		

NOTE.—Values are rated as fair.

PALOUSE RIVER AT HOOPER, WASH.

The gaging station at Hooper, Wash., was originally established April 1, 1897, by the land department of the Northern Pacific Railway. The United States Geological Survey assumed charge September 9, 1897, and moved the station about 1 mile downstream.

The measurements are of value in showing the amount of water available for use on lands of Washtucna Valley and in the section north of Pasco. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 171, where are given also references to publications that contain data for previous years.

Daily gage height, in feet, of Palouse River at Hooper, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.5	3.6	4.75	5.3	3.2	3.7	1.65	0.9	0.8	0.8	0.9	1.6
2	1.6	3.5	4.7	5.75	3.0	3.5	1.6	.9	.8	.8	.9	1.6
3	1.55	3.6	4.4	6.0	2.4	2.45	1.6	.85	.8	.8	.95	1.6
4	1.5	4.05	4.1	5.85	2.3	2.7	1.6	.8	.8	.8	1.0	1.55
5	1.6	3.5	3.6	5.7	2.15	3.5	1.6	.8	.8	.8	1.0	1.5
6	1.65	3.5	3.9	5.6	2.5	3.05	1.5	.8	.8	.8	1.0	1.65
7	1.7	3.05	3.6	4.4	2.4	2.45	1.4	.8	.8	.8	1.05	1.8
8	1.8	2.9	3.6	4.4	2.2	2.55	1.35	.8	.8	.8	1.15	2.05
9	2.0	2.9	3.6	4.3	2.2	2.6	1.5	.75	.8	.8	1.2	3.05
10	1.95	2.8	3.8	4.9	2.2	2.4	1.4	.75	.8	.8	1.35	2.7
11	1.95	2.8	5.15	4.8	2.15	2.55	1.35	.75	.8	.8	1.6	2.7
12	1.85	2.85	4.9	4.75	2.1	2.4	1.3	.75	.8	.8	1.8	2.9
13	1.85	2.8	3.4	4.6	2.0	2.3	1.25	.75	.8	.85	2.1	3.05
14	2.0	2.7	4.9	3.6	2.0	2.3	1.2	.8	.8	.9	2.4	3.4
15	2.35	2.75	4.0	3.4	2.0	2.25	1.7	.8	.8	.9	3.3	2.8
16	2.3	2.7	3.6	3.9	2.1	2.2	1.4	.8	.8	.9	3.8	2.7
17	2.35	3.1	3.5	3.5	2.1	2.2	1.3	.75	.8	.9	4.1	2.7
18	2.3	3.2	3.5	3.4	2.05	2.1	1.2	.75	.8	.9	4.4	2.6
19	2.2	3.3	3.3	3.4	2.05	2.1	1.15	.7	.8	.9	3.05	2.6
20	1.95	5.05	3.6	3.4	2.05	2.05	1.15	.7	.8	.9	2.6	3.7
21	1.85	6.1	3.5	3.25	2.05	2.0	1.1	.7	.8	.9	2.5	6.1
22	2.0	6.35	2.95	3.1	2.0	2.0	1.05	.7	.8	.9	2.3	8.7
23	2.35	5.7	3.2	3.05	2.0	2.0	1.05	.7	.8	.9	2.2	9.8
24	3.15	5.65	3.25	3.0	1.9	1.95	1.05	.7	.8	.9	2.1	8.2
25	3.3	5.15	3.4	2.9	1.85	1.85	1.05	.7	.8	.9	2.0	7.1
26	3.7	5.0	3.6	3.4	1.8	1.6	1.05	.7	.8	.9	1.85	6.8
27	4.2	4.8	4.9	3.1	1.75	1.7	1.0	.7	.8	.95	1.6	7.0
28	4.05	4.75	5.4	3.0	1.7	1.6	1.0	.7	.8	.95	1.5	7.4
29	4.0	......	6.1	2.9	2.2	1.65	.95	.7	.8	.95	1.5	6.8
30	3.9	......	6.4	3.0	3.8	1.75	.95	.7	.8	.95	1.6	7.1
31	3.6	......	5.8	......	2.7	......	.95	.75	......	.9	......	7.6

Rating table for Palouse River at Hooper, Wash., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.60	10	1.70	110	2.80	331	3.90	670	6.00	1,965
0.70	13	1.80	125	2.90	355	4.00	715	6.20	2,120
0.80	17	1.90	141	3.00	380	4.20	805	6.40	2,280
0.90	22	2.00	158	3.10	405	4.40	900	6.60	2,440
1.00	28	2.10	176	3.20	430	4.60	1,015	6.80	2,620
1.10	36	2.20	195	3.30	457	4.80	1,135	7.00	2,800
1.20	46	2.30	215	3.40	486	5.00	1,265	8.00	3,780
1.30	57	2.40	236	3.50	517	5.20	1,400	9.00	4,900
1.40	69	2.50	259	3.60	551	5.40	1,540	10.00	6,200
1.50	82	2.60	283	3.70	588	5.60	1,680		
1.60	96	2.70	307	3.80	628	5.80	1,820		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903–1906 and is well defined between gage heights 0.8 feet and 10.0 feet.

Monthly discharge of Palouse River at Hooper, Wash., for 1906.

[Drainage area, 2,210 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	805	82	269	16,500	0.122	0.14
February	2,240	307	784	43,500	.355	.37
March	2,280	367	857	52,700	.388	.45
April	1,960	355	842	50,100	.381	.43
May	628	110	208	12,800	.094	.11
June	588	96	231	13,700	.105	.12
July	110	25	56.8	3,490	.026	.03
August	22	13	15.3	941	.0069	.01
September	17	17	17.0	1,010	.0077	.01
October	25	17	20.4	1,250	.0092	.01
November	900	22	196	11,700	.089	.10
December	5,920	82	1,360	83,600	.615	.71
The year	5,920	13	405	291,000	.183	2.49

NOTE.—Values are rated as good.

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made in Snake River drainage basin in 1906:

Asotin Creek at Asotin, Wash.—This station, which was discontinued December 31, 1905, is described in Water-Supply Paper No. 178, page 167. A measurement was made December 21, 1906.

Width, 52 feet; area, 68 square feet; gage height, 3.97 feet; discharge, 290 second-feet.

Bear Creek near Wallowa, Oreg.—The reference point is on top of the lower end of the left floor beam; gage heights are distances below reference point.

May 22, width 35 feet; area, 55 square feet; gage height, —7.66 feet; discharge, 226 second-feet.

June 26, width, 37 feet; area, 62 square feet; gage height, —7.45 feet; discharge, 259 second-feet.

Five point Creek near Hilgard, Oreg.—A measurement was made just above the mouth March 10, 1906. The water surface was 6.34 feet below the top of the highway bridge floor, upstream side, at a point 23 feet from the right end of the floor.

Width, 25 feet; area, 45 square feet; discharge, 157 second-feet.

A measurement was made at low water December 4, 1906. The water surface was 7.15 feet below a bent spike in the downstream side of the top log of the right abutment of the highway bridge.

Width, 20 feet; area, 21 square feet; discharge, 7.4 second-feet.

Minam Creek near Lovely, Oreg.—The discharge of this stream was found December 9, 1906, by taking the difference of the discharges of Wallowa River above and below its mouth. Discharge, 228 second-feet.

Wallowa River near Lovely, Oreg.—A measurement was made at medium stage, December 9, 1906, at the footbridge just below Canyon stage stations and above the mouth of Minam Creek. The water surface was 1.08 feet below a small ledge of projecting rock on the right bank, 9.0 feet vertically underneath a point on the top of the downstream log of the footbridge, 7.5 feet from the right end of the log.

Width, 85 feet; area, 186 square feet; discharge, 549 second-feet.

Miscellaneous measurements in Snake River drainage basin in 1906.

Date.	Stream.	Locality.	Width.	Area of section.	Discharge.
			Feet.	*Sq. ft.*	*Sec.-ft.*
January 9	Boise River	Below Barber dam and 7 miles above Boise, Idaho.	144	261	562
April 4	Burnt River	Huntington, Oreg.	78	156	696
August 6	Cedar Creek	In canyon, 8 miles above Mackay, Idaho.	10	6.2	12.5
July 19	North Fork Buffalo River	At most northerly meadows, Wyoming.	62	75	165
September 8	John Day River	Junction with South Fork Snake River, Wyoming.	42	104	592

WALLA WALLA RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Walla Walla River heads on the northwestern slope of the Blue Mountains in northeastern Oregon and southeastern Washington, flows westward, and unites with the Columbia at Wallula, Wash. The Blue Mountains have an elevation of approximately 2,000 feet above the surrounding country; their northwestern slope is drained by the numerous tributaries of the Walla Walla and their southeastern slope by those of Grande Ronde River, a tributary of the Snake. The drainage basin is a broad, triangular-shaped area, aggregating 1,050 square miles. Except on the mountain slopes the area is timberless, being composed of rolling table-lands devoted largely to the production of wheat. The valleys are level tracts in which irrigation has reached a high stage of development. The rainfall at Walla Walla, Wash., is about 18 inches per annum. The principal tributaries of the stream are Little Walla Walla River, Mill Creek, on which the city of Walla Walla is situated, Garrison Creek, Yellowhawk Creek, Cottonwood Creek, and South Fork of Walla Walla River.

The main stream and its tributaries are used extensively for irrigation and power. The power plant of the Northwestern Gas and Electric Company, from which the cities of Pendleton, Walla Walla, Weston, and neighboring towns are connected by an electric line, is located on South Fork of Walla Walla River, about 12 miles above Milton.

WALLA WALLA RIVER NEAR MILTON, OREG.

This station was established August 12, 1905, to replace the station at Milton, Oreg., one-half mile below. It was located near the old city reservoir, 1½ miles above Milton, but the gage, cable, and bench mark were destroyed by flood May 30, 1906, and on August 16, 1906, the station was reestablished at West's highway bridge, 3 miles above Milton. A small ditch heads just above the bridge.

The channel is straight above the station and curved below. The water is shallow and the current swift. The banks are low and liable to overflow. The bed of the stream is composed of clean sand and gravel and liable to shift. There is one channel at all stages.

Measurements are made from the bridge. The initial point is the face of the right abutment.

The gage, which is read by Maud Osborn, is a 2 by 6 inch timber spiked vertically to the right abutment. The bench mark is a 20-penny spike in pole 1170 of a transmission line at the southwest corner of the bridge; elevation, 9.03 feet above the datum of the gage.

The conditions at the old station and the bench marks are described in Water-Supply Paper No. 178, page 178, where are given also references to publications that contain data for previous years.

Discharge measurements of Walla Walla River near Milton, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
February 19	R. S. Hall	60	91	[a] 4.62	413
March 23	Cupper and Buchanan	47	60	[a] 4.11	181
May 22	P. A. Cupper	45	66	[a] 4.13	187
June 28 [b]	do	45	59		186
July 21 [b]	do	44	56		112
August 4 [b]	do	43	50		99
August 29	do	43	52	[c] 1.63	97
December 11	H. McGlashan	63	72	[c] 2.20	300

[a] Gage near city reservoir.

[b] Measured by wading at mouthof Couse Creek.

[c] Gage at West's bridge.

Daily gage height, in feet, of Walla Walla River near Milton, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Sept.	Oct.	Nov.	Dec.
1	4.02	4.28	4.38	4.70	4.45	[a] 1.35	1.65	1.75	1.95
2	4.00	4.28	4.32	4.60	4.45	1.55	1.75	1.75	1.95
3	4.00	4.20	4.28	4.60	4.48	1.45	1.75	1.65	1.85
4	4.02	4.20	4.28	4.60	4.45	1.65	1.65	1.70	1.85
5	4.10	4.18	4.22	4.60	4.35	1.65	1.85	1.75	1.90
6	4.22	4.15	4.22	4.62	4.35	1.55	1.75	1.75	1.95
7	4.32	4.10	4.25	4.62	4.30	1.35	1.75	1.85	2.05
8	4.30	4.10	4.30	4.65	4.30	1.65	1.65	1.85	2.05
9	4.22	4.08	4.38	4.70	4.30	1.55	1.75	1.90	2.15
10	4.20	4.08	4.38	4.60	4.30	1.65	1.75	1.95	2.05
11	4.20	4.08	4.35	4.55	4.30	1.55	1.75	2.65	2.05
12	4.18	4.05	4.32	4.45	4.30	1.55	1.65	2.85	2.35
13	4.22	4.02	4.25	4.42	4.25	1.65	1.75	2.75	2.30
14	4.22	4.02	4.22	4.48	4.25	1.75	1.75	2.95	2.20
15	4.20	4.05	4.22	4.50	4.28	1.75	1.75	3.25	2.15

Daily gage height, in feet, of Walla Walla River near Milton, Oreg., in 1906—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Sept.	Oct.	Nov.	Dec.
16	4.28	4.05	4.20	4.58	4.22	1.75	1.85	3.65	2.30
17	4.22	4.05	4.15	4.55	4.15	1.75	1.75	2.95	2.30
18	4.20	4.20	4.12	4.52	4.25	1.75	1.75	2.75	2.25
19	4.18	4.60	4.10	4.52	4.25	1.65	1.75	2.65	2.35
20	4.12	4.60	4.10	4.52	4.12	1.75	1.75	2.55	2.15
21	4.10	4.60	4.10	4.62	4.13	1.75	1.65	2.35	4.00
22	4.12	4.55	4.10	4.70	4.12	1.75	1.75	2.15	3.40
23	4.18	4.45	4.10	4.65	4.13	1.85	1.75	2.05	3.00
24	4.40	4.42	4.25	4.60	4.12	1.85	1.70	1.95	2.95
25	4.50	4.38	4.30	4.52	4.10	1.75	1.75	1.95	2.95
26	4.45	4.35	4.32	4.48	4.12	1.75	1.75	1.95	2.90
27	4.40	4.40	4.62	4.45	4.13	1.75	1.65	1.90	2.85
28	4.32	4.40	4.62	4.45	4.12	1.85	1.75	1.85	2.85
29	4.30	....	4.58	4.45	5.90	1.75	1.70	1.80	2.80
30	4.28	....	4.60	4.45	(b)	1.65	1.75	1.85	2.75
31	4.25	....	4.72	....	....	....	1.75	....	2.75

[a] On gage at West's bridge.

[b] Gage and cable washed away by flood.

Rating table for Walla Walla River near Milton, Oreg., from January 1 to May 29, 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
3.80	94	4.10	175	4.30	251	4.50	349	4.70	469
3.90	117	4.20	210	4.40	297	4.60	406	4.80	534
4.00	144								

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905-6 and is well defined below gage height 4.2 feet.

Monthly discharge of Walla Walla River near Milton, Oreg., for 1906.

[Drainage area, 130 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	349	144	221	13,600	1.70	1.96
February	406	150	239	13,300	1.84	1.92
March	482	175	260	16,000	2.00	2.31
April	469	307	384	22,800	2.95	3.29
May 1-29	1,370	175	274	15,800	2.11	2.28
The period				81,500		

NOTE.—Values are rated as excellent.

SOUTH FORK OF WALLA WALLA RIVER NEAR MILTON, OREG.

This station was originally established February 15, 1903, 6 miles above the mouth of the river and 12 miles from Milton, Oreg. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 176, where are given also references to publications that contain data for previous years.

The flood of May 30, 1906, entirely changed the channel. On August 10, 1906, a new station was established one-fourth mile above the headgate of the Northwestern Gas and Electric Company's pipe line. This point is above all diversions.

The channel is straight for 200 feet above and below the station. The banks are low and liable to overflow. There is one channel at all stages. The bed of the stream is of gravel and will change during high floods. The current is swift at all stages.

Measurements are made by wading 17 feet below the gage. The initial point for soundings is a blaze on a cottonwood tree on the left bank.

Gage heights are furnished by the Northwestern Gas and Electric Company, through Mr. Paul Young. The gage is a 2 by 6 inch timber, spiked in a vertical position to a tree on the left bank. The bench mark is a spike in the roots of a large cottonwood tree on the left bank, 10 feet from the gage; elevation, 7.74 feet above the datum of the gage.

Discharge measurements of South Fork of Walla Walla River near Milton, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
February 20	R. S. Hall	48	71	[a] 2.10	390
March 23	P. A. Cupper	45	41	[a] 1.50	159
May 24	do	45	48	[a] 1.66	171
August 10	J. C. Stevens	45	49	[b] 2.50	120
December 13	H. McGlashan	42	56	[b] 3.73	183

[a] Gage at bridge. [b] Gage at headgate.

Daily gage height, in feet, of South Fork of Walla Walla River near Milton, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Aug.	Sept.
1	....	1.7	1.7	2.0	2.0	1.2	....	2.5
2	1.55	1.7	1.65	2.0	2.0	....	....	2.5
3	1.55	....	1.65	2.0	....	1.0	....	2.5
4	....	1.65	1.65	2.0	2.0	....	....	2.5
5	1.6	1.6	1.6	2.0	1.95	....	....	2.5
6	1.7	1.6	1.6	2.0	1.9	....	....	2.5
7	....	1.6	1.6	2.1	1.85	....	....	2.5
8	1.65	1.6	1.7	2.1	1.8	....	....	2.5
9	1.65	1.6	....	2.1	1.85	....	....	2.52
10	1.7	....	1.7	2.0	....	....	2.5	2.52
11	1.65	1.55	....	....	1.9	....	2.5	2.51
12	....	1.55	....	1.8	1.9	....	2.53	2.5
13	1.65	1.55	....	1.8	1.85	....	2.55	2.55
14	1.65	1.55	....	1.8	1.85	....	2.52	2.56
15	1.65	1.55	1.5	1.9	1.8	....	2.52	2.55
16	1.7	1.55	....	1.9	....	....	2.51	....
17	1.7	....	....	1.9	1.75	....	2.51	....
18	1.7	....	1.5	1.9	1.7	....	2.52	....
19	1.7	2.2	1.5	1.9	1.7	....	2.5	....
20	....	2.0	1.5	1.95	1.7	....	2.5	....
21	1.65	2.1	1.5	2.0	....	....	2.5	....
22	1.65	2.0	....	2.2	1.7	....	2.57	....
23	1.8	1.9	1.5	2.2	1.7	....	2.55	....
24	1.8	1.8	1.6	2.1	....	....	2.53	....
25	1.95	1.8	1.7	2.05	....	....	2.52	....
26	1.9	1.8	2.0	2.0	1.7	....	2.52	....
27	1.8	1.75	2.0	1.95	1.7	....	2.52	....
28	1.75	1.75	2.0	1.9	1.7	....	2.5	....
29	1.7	....	2.0	1.95	2.86	....	2.5	....
30	1.7	....	1.95	2.0	....	....	2.5	....
31	1.7	....	2.15	....	....	....	2.5	....

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made in Walla Walla River drainage basin during 1906:

Couse Creek near Milton, Oreg.—March 23, discharge, 10 second-feet; August 10, dry.

Dry Creek near Milton, Oreg.—A measurement was made 500 feet below the crossing of Finis Irrigation Company's flume. The water surface was 0.5 foot below the bench mark on a rock 50 feet above the section.

Width, 18 feet; area, 10 square feet; discharge, 13 second-feet.

Walla Walla River at Milton, Oreg.—The following discharges were computed from slope measurements for the spring and fall floods:

May 30, width, 316 feet; area, 924 square feet; discharge, 8,130 second-feet.
November 14, width, 281 feet; area, 632 square feet; discharge, 4,550 second-feet.

North Fork of Walla Walla River near Milton, Oreg.—Measurements were made near the junction with South Fork.

March 23, width, 17 feet; area, 12 square feet; discharge, 28 second-feet.
March 24, width, 16 feet; area, 8 square feet; discharge, 21 second-feet.
August 29, width, 12 feet; area, 12 square feet; discharge, 7 second-feet.

UMATILLA RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Umatilla River rises in the western slopes of the Blue Mountains in northeastern Oregon, flows westward, and joins Columbia River at the town of Umatilla. Its drainage area is timberless except on the mountain slopes, and is composed of rolling table-lands devoted largely to the production of wheat. The rainfall on the drainage area varies from 24 inches on the headwaters to 10 inches at the mouth.

The waters of this stream are used for both power and irrigation purposes, and it is one of the most important rivers in the State.

UMATILLA RIVER AT GIBBON, OREG.

This station was established July 22, 1896. It is located about 1 mile west of Bingham Springs Railroad station (Gibbon post-office), Oreg. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 181, where are given also references to publications that contain data for previous years.

The gage at this station was read during a portion of 1906 by J. C. Hilliard. The gage was washed out May 30, 1906, and on December 3 a new one was installed about 50 feet upstream from the cable on the left bank. It consists of a 2 by 6 inch timbers, in two sections, spiked to cottonwood trees. The bench mark is a spike in the root of a 16-inch yellow pine, 415 feet from the initial point for soundings, 160 feet from the railroad track, and 20 feet upstream from the line of the cable extended; elevation, 9.03 feet above the datum of the gage.

Discharge measurements of Umatilla River at Gibbon, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
February 1	R. S. Hall	53	67	[a]1.80	351
March 14	do	55	80	[a]1.85	415
April 2	do	117	260	[a]3.28	1,680
April 21	J. C. Stevens	112	203	[a]2.80	1,310
May 26	R. S. Hall	44	44	[a]1.40	203
June 6	do	112	307		1,390
July 9	do	86	80		102
December 3	Stevens and McGlashan	102	132	[b]1.50	183

[a] Old gage. [b] New gage.

Daily gage height, in feet, of Umatilla River at Gibbon, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Dec.	Day.	Jan.	Feb.	Mar.	Apr.	May.	Dec.
1	1.45		1.9	3.7	2.2		17	1.6		1.7	2.4	1.5	1.9
2	1.4	1.8	1.9	3.25			18	1.6	1.7	1.7	2.4	1.45	1.9
3	1.4	1.8	1.8	2.9	2.0	[a]1.5	19	1.55	2.4		2.4	1.4	1.9
4	1.5	1.8	1.8	2.9	2.0	1.5	20	1.55	2.3	1.5	2.7	1.4	5.2
5	1.5	1.8	1.8	2.8	2.0	1.5	21	1.5	2.4	1.5	2.8	1.4	5.8
6		1.7	1.8	2.9	1.95	1.6	22	1.5	2.3	1.5	2.9	1.4	4.5
7	1.8	1.6	1.8	3.3	1.9	2.1	23		2.2	1.5		1.4	3.8
8	1.7	1.6	2.05		1.8	2.5	24	2.0	2.0	2.0	2.5	1.4	3.6
9	1.65	1.6	2.3		1.8	2.4	25	2.25	2.0	2.7	2.5	1.4	3.7
10	1.65	1.55	2.4	2.9	1.75	2.2	26	2.1	2.0	2.75	2.5	1.4	4.1
11	1.6	1.5		2.8	1.75	2.2	27	2.0		3.4	2.4	1.4	3.7
12	1.7	1.5	2.0	2.5	1.7	2.2	28	1.95		3.3	2.4	1.7	3.6
13	1.65	1.5	1.9	2.5	1.7	2.1	29	1.9		3.0	2.4		3.4
14	1.6	1.5		2.4	1.7	2.0	30	1.9		3.5	2.3	(b)	3.1
15	1.6	1.5		2.5	1.6	2.0	31	1.85		4.1			3.0
16	1.6	1.5	1.7	2.4	1.5	1.9							

[a] New gage installed December 3. No relation determined for the two gages.
[b] Gage destroyed by flood.

Rating table for Umatilla River at Gibbon, Oreg., from January 1 to May 29, 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.40	190	2.00	555	2.60	1,075	3.20	1,660	3.80	2,305
1.50	233	2.10	635	2.70	1,170	3.30	1,765	3.90	2,415
1.60	284	2.20	720	2.80	1,265	3.40	1,870	4.00	2,530
1.70	343	2.30	805	2.90	1,360	3.50	1,975	4.10	2,645
1.80	408	2.40	895	3.00	1,460	3.60	2,085		
1.90	479	2.50	985	3.10	1,560	3.70	2,195		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905-6 and is well defined below gage heights 3.0 feet.

Monthly discharge of Umatilla River at Gibbon, Oreg., for 1906.

[Drainage area, 353 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	762	190	352	21,600	1.00	1.15
February	895	233	441	24,500	1.25	1.30
March	2,640	233	734	45,100	2.08	2.40
April	2,200	805	1,190	70,800	3.37	3.76
May 1-28	720	190	344	19,100	.975	1.02
The period				181,000		

NOTE.—Values January to May are rated as good.

UMATILLA RIVER AT YOAKUM, OREG.

This station was established May 5, 1903. It is located one-half mile east of Yoakum, a station of the Oregon Railroad and Navigation Company, at what is known as the Yoakum wagon bridge. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 185, where are given also references to publications that contain data for previous years.

Discharge measurements of Umatilla River at Yoakum, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 19	R. S. Hall	75	224	4.45	516
April 20	J. C. Stevens	76	352	5.98	1,570
June 2	R. S. Hall		531	8.30	4,780
July 11	do	74	154	3.20	93
November 26[a]	H. McGlashan	76	229	4.05	284

[a] Some slack water and eddies.

Daily gage height, in feet, of Umatilla River at Yoakum, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.3	5.3	5.3	8.05	5.0	9.5	3.7	2.7	2.8	2.9	3.2	3.9
2	4.3	5.1	5.3	7.25	5.0	8.0	3.6	2.7	2.8	2.9	3.2	3.9
3	4.1	5.0	5.2	7.0	4.9	7.4	3.5	2.7	2.8	3.0	3.2	3.9
4	4.1	4.8	5.2	7.1	4.9	7.4	3.5	2.7	2.8	3.0	3.1	3.9
5	4.1	4.6	5.1	7.2	4.7	7.3	3.4	2.7	2.8	3.0	3.2	3.9
6	4.2	4.5	5.0	7.2	4.7	7.2	3.3	2.7	2.8	3.0	3.2	4.0
7	4.6	4.5	4.9	7.2	4.5	6.9	3.3	2.7	2.8	3.0	3.2	4.3
8	4.6	4.4	5.1	7.2	4.4	6.7	3.2	2.7	2.8	3.0	3.3	4.6
9	4.04	4.4	5.5	7.3	4.4	6.5	3.1	2.7	2.8	3.0	3.5	4.8
10	4.2	4.3	5.7	6.8	4.3	6.2	3.1	2.7	2.8	3.0	3.5	4.8
11	4.3	4.3	5.8	6.5	4.3	5.7	3.1	2.7	2.8	3.0	3.5	4.8
12	4.3	4.2	5.5	6.1	4.2	5.4	3.1	2.8	2.8	3.0	3.5	4.7
13	4.3	4.1	5.5	6.0	4.2	5.0	3.1	3.0	3.0	3.0	3.5	4.6
14	4.3	4.1	5.2	6.0	4.2	4.9	3.1	3.0	3.1	3.0	5.2	4.5
15	4.2	4.0	5.1	6.1	4.2	4.8	3.0	3.0	3.1	3.0	5.9	4.5
16	4.2	4.0	5.0	6.4	4.2	4.8	3.0	3.0	3.1	3.5	5.7	4.5
17	4.3	4.0	4.9	6.3	4.0	4.6	3.0	3.0	3.0	3.5	5.0	4.4
18	4.3	4.0	4.5	6.1	4.0	4.5	3.0	2.9	3.0	3.5	4.9	4.4
19	4.3	5.0	4.6	6.0	3.9	4.5	3.0	2.9	3.0	3.5	4.5	4.5
20	4.3	5.8	4.6	6.0	3.9	4.4	2.9	2.8	3.0	3.5	4.5	6.8
21	4.2	5.7	4.6	6.2	3.9	4.3	2.9	2.8	3.0	3.5	4.5	9.0
22	4.2	5.7	4.7	6.4	3.9	4.3	2.9	2.8	3.0	3.5	4.4	7.8
23	4.3	5.6	4.7	6.3	3.9	4.2	2.8	2.8	2.9	3.6	4.3	7.0
24	4.8	5.6	5.9	5.9	3.9	4.2	2.8	2.8	2.9	3.6	4.3	6.5
25	5.3	5.5	6.1	5.7	3.9	4.1	2.8	3.0	2.9	3.6	4.2	6.5
26	5.8	5.4	6.7	5.45	3.9	4.0	2.7	2.9	2.9	3.6	4.0	7.0
27	5.7	5.3	7.2	5.3	3.8	4.0	2.7	2.9	2.9	3.6	4.0	7.1
28	5.6	5.3	7.4	5.3	4.0	4.1	2.7	2.8	2.9	3.5	4.0	6.5
29	5.4	....	7.0	5.2	6.65	3.9	2.7	2.8	2.9	3.4	4.0	6.4
30	5.4	....	7.2	5.2	[a]15.0	3.8	2.7	2.8	2.9	3.3	4.0	6.4
31	5.3	....	7.75	....	13.0	....	2.7	2.8	....	3.3	....	6.4

[a] Estimated; water overflowed bottom lands.

Rating table for Umatilla River at Yoakum, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.70	28	3.80	225	4.90	755	6.00	1,645	8.20	4,590
2.80	37	3.90	253	5.00	820	6.20	1,840	8.40	4,940
2.90	47	4.00	284	5.10	890	6.40	2,040	8.60	5,300
3.00	59	4.10	320	5.20	965	6.60	2,260	8.80	5,680
3.10	73	4.20	360	5.30	1,040	6.80	2,500	9.00	6,060
3.20	89	4.30	410	5.40	1,120	7.00	2,750	10.00	8,190
3.30	107	4.40	460	5.50	1,200	7.20	3,020	11.00	10,750
3.40	127	4.50	515	5.60	1,285	7.40	3,310	12.00	13,730
3.50	149	4.60	570	5.70	1,370	7.60	3,610	13.00	17,000
3.60	173	4.70	630	5.80	1,460	7.80	3,930	14.00	20,400
3.70	199	4.80	690	5.90	1,550	8.00	4,250	15.00	23,900

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903–1906 and is well defined below gage height 9.7 feet.

Monthly discharge of Umatilla River at Yoakum, Oreg., for 1906.

[Drainage area, 1,200 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	1,460	298	587	36,100	0.489	0.56
February	1.460	284	697	38,700	.581	.60
March	3,850	515	1,370	84,200	1.14	1.31
April	4,340	965	2,090	124,000	1.74	1.94
May	23,900	225	1,770	109,000	1.47	1.70
June	7,080	225	1.460	86,900	1.22	1.36
July	199	28	72.7	4,470	.061	.07
August	59	28	39.4	2,420	.033	.04
September	73	37	48.4	2,880	.040	.04
October	173	47	105	6,460	.088	.10
November	1,550	73	384	22,800	.320	0.36
December	6,060	253	1,360	83,600	1.13	1.30
The year	23,900	28	832	602,000	.693	9.38

NOTE.—Values are rated as follows: January, February, and July to November, good; March to June and December, excellent.

UMATILLA RIVER AT UMATILLA, OREG.

This station was established October 21, 1903. It is located about 1 mile above Umatilla, Oreg., and about one-fourth mile below the diversion dam of the Oregon Land and Water Company. To obtain the total discharge of the river, the discharge of the irrigation ditch must be added to that of the river at the gage. The gage was read during 1906 by N. E. Newton. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 188, where are given also references to publications that contain data for previous years.

Discharge measurements of Umatilla River at Umatilla, Oreg., in 1905–6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1905.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
December 20	R. S. Hall	167	165	3.08	363
1906.					
February 22	R. S. Hall	177	328	4.00	1,330
March 17	do	174	219	3.40	652
April 19	J. C. Stevens	176	328	4.05	1,440
May 28	R. S. Hall	154	105	2.70	169
May 31 [a]	Stevens and Lewis		1,620	11.00	17,500
June 11	R. S. Hall	176	330	4.05	1,360
June 23	do	165	178	3.02	414
August 11 [b]	J. C. Stevens			1.10	0.3
November 25	H. McGlashan	165	163	3.00	348

[a] Measured by floats.

[b] Stream bed dry except at left edge.

Daily gage height, in feet, of Umatilla River at Umatilla, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.9			5.4	3.5	8.0	2.65	1.0	1.2	1.8	2.3	2.8
2		3.4	3.8			6.3				2.1	2.3	
3	2.8			4.9	3.4	5.5	2.5	1.0	1.2	2.15	2.25	2.75
4		3.35	3.6							2.1	2.3	
5	2.8			4.7	3.3	5.4	2.25	1.0	1.2	2.0	2.3	2.7
6		3.3	3.5							2.0	2.35	
7	3.0			4.7	3.15	5.0	2.0	1.0	1.2	2.1	2.4	2.7
8		3.25	3.4							2.1	2.4	
9	3.25			4.8	3.05	4.5	1.75	1.0	1.2	2.1	2.4	3.1
10		3.2	3.7							2.1	2.6	
11	3.2			4.6	2.9	4.1	1.7	1.1	1.2	2.1	2.6	3.2
12		3.0	3.7							2.1	2.6	
13	3.1			4.2	2.85	3.8	1.6	1.1	1.25	2.1	2.6	3.3
14		2.95	3.9							2.2	2.6	
15	3.1			4.0	2.9	3.5	1.3	1.1	1.3	2.2	3.9	3.3
16		2.9	3.6			3.7				2.15	3.8	
17	3.1			4.2	2.85	3.6	1.2	1.1	1.8	2.2	3.7	3.2
18		3.0	3.3							2.2	3.6	3.15
19	3.0			4.1	2.7	3.3	1.1	1.1	1.9	2.2	3.4	3.1
20		3.5	3.2							2.3	3.3	3.0
21	3.0			4.0	2.65	3.15	1.1	1.1	1.85	2.3	3.2	5.2
22		4.1	3.2							2.25	3.1	6.1
23	3.0			4.1	2.7	3.0	1.1	1.1	1.85	2.25	3.1	5.2
24		3.9	3.2							2.3	3.0	4.7
25	3.6			3.9	2.6	2.9	1.0	1.2	1.85	2.3	3.0	4.5
26		3.8	4.2							2.3	2.95	4.6
27	3.85			3.7	2.6	2.7	1.1	1.2	1.8	2.3	2.9	4.9
28		3.7	4.8		2.7					2.3	2.9	4.65
29	3.6			3.6	2.8	2.8	1.1	1.2	1.8	2.35	2.9	4.45
30			4.7		6.85					2.4	2.85	4.3
31	3.5				10.2		1.1	1.2		2.35		4.3

Rating table for Umatilla River at Umatilla, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.10	0.1	2.10	21	3.10	400	4.20	1,670	6.20	5,220
1.20	.2	2.20	32	3.20	485	4.40	1,975	6.40	5,620
1.30	.3	2.30	45	3.30	575	4.60	2,290	6.60	6,030
1.40	.4	2.40	60	3.40	675	4.80	2,620	6.80	6,450
1.50	.5	2.50	80	3.50	775	5.00	2,960	7.00	6,880
1.60	.7	2.60	108	3.60	885	5.20	3,310	8.00	9,200
1.70	1.5	2.70	146	3.70	1,000	5.40	3,675	9.00	11,800
1.80	3.5	2.80	194	3.80	1,125	5.60	4,050	10.00	14,580
1.90	7.5	2.90	252	3.90	1,250	5.80	4,435	11.00	17,500
2.00	13	3.00	320	4.00	1,385	6.00	4,825		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903–1906 and is well defined between gage heights 2 feet and 7 feet.

Monthly discharge of Umatilla River at Umatilla, Oreg., for 1906.

[Drainage area, 2,130 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	1,190	194	492	30,300	0.231	0.27
February	1,520	252	691	38,400	.324	.34
March	3,070	485	1,130	69,500	.531	.61
April	3,680	830	1,860	111,000	.873	.97
May	15,200	108	983	60,400	.462	.53
June	9,200	146	1,690	101,000	.793	.88
July	127	0	15.0	922	.007	.01
August	0.2	0	.094	5.8	.000044	.00005
September	7.5	0.2	2.46	146	.0012	.001
October	60	3.5	31.9	1,960	.015	.02
November	1,250	38.5	323	19,200	.152	.17
December	5,020	146	1,180	72,600	.554	.64
The year	15,200	0	700	505,000	.329	4.45

NOTE.—Values are rated as follows: January to June, November and December, excellent; July and October, fair; August and September, approximate. Discharges interpolated for days on which gage heights were not observed.

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made in Umatilla River drainage basin during 1906:

Meacham Creek at Gibbon, Oreg.—A measurement was made from the highway bridge one-half mile east of the Bingham Springs railroad station February 1, 1906. The water surface was 8.72 feet below the lower end of the floor plank, 5.3 feet from the left end of the truss.

Width, 45 feet; area, 130 square feet; discharge, 189 second-feet.

Minnehaha Spring near Hermiston, Oreg.—The following measurement was made May 7, 1906:

Width, 6 feet; area, 2.7 feet; discharge, 2.6 second-feet.

Wild Horse Creek near Pendleton, Oreg.—A measurement was made February 26, 1906. The water surface was 7.42 feet below a tack in the upstream side of the bridge.

Width, 16 feet; area, 13 square feet; discharge, 22 second-feet.

Discharge measurements of Umatilla River near Fosters,[a] Oreg., in 1905-6.

Date.	Width.	Area of section.	Gage height.	Discharge.
1905.	*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
November 11	66	55	1.08	40
December 4	82	106	1.78	227
December 22	115	159	2.10	413
December 28	102	124	1.84	291
1906.				
January 5	100	115	1.80	219
January 13	116	157	2.18	420
January 17	116	166	2.18	429
January 29	138	267	2.90	1,090
February 9	117	161	2.12	423
February 17	105	129	1.85	284
March 2	138	272	2.95	1,140

[a] At highway bridge, 4 miles below Echo, Oreg.

Discharge measurements of Umatilla River at Pendleton, Oreg., in 1906.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
January 31[a]	89	297	....	582
February 3[b]	104	144	4.48	540
February 14[a]	82	246	4.20	253
February 26[b]	115	196	4.78	903
March 21[a]	85	254	4.28	317

[a] From Oregon Railroad and Navigation Company's railway bridge.
[b] From highway bridge.

CANALS IN UMATILLA RIVER VALLEY, OREGON.

The points of diversion of these canals and the points of measurement are described in Water-Supply Paper No. 178, pages 190 to 201, where are also given the data collected during 1905.

Discharge measurements of canals in Umatilla River Valley, Oregon, in 1906.

HORSESHOE IRRIGATION COMPANY'S CANAL, YOAKUM.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
March 3	4	2	....	2.5
May 4	3.4	1.4	....	.87

SLUSHER AND GOULD CANAL, NOLIN.

Date.	Width.	Area of section.	Gage height.	Discharge.
January 6	4.2	3.5	0.77	2.0
March 3	4.1	1.6	.42	.9

CHARLES LISLE CANAL, ECHO.

Date.	Width.	Area of section.	Gage height.	Discharge.
January 6	7.6	6.9	0.99	1.9
January 17	7.7	7.0	.94	1.8
February 8	7.3	5.8	.82	1.8
February 17	9.8	9.2	1.24	.94
May 4	8.2	6.9	.98	3.85

MILL CANAL, ECHO.

Date.	Width.	Area of section.	Gage height.	Discharge.
January 6	9.4	7.1	1.58	5.2
January 13	9.7	7.9	1.67	6.6
January 17	9.8	8.0	1.58	7.0
February 8	5.9	1.7	.89	.56
February 17	7.3	4.6	1.40	4.0
March 3	8.0	7.2	1.82	7.8
May 4	5.5	1.9	.99	1.3

MILL CANAL WASTEWAY, ECHO.

Date.	Width.	Area of section.	Gage height.	Discharge.
1905.				
December 28	7.0	5.2	1.10	3.8
1906.				
January 6	7.0	5.8	1.13	4.3
January 17	7.2	7.0	1.20	5.0
February 8	4.8	1.4	.34	0.18
February 17	6.7	5.02	.92	4.86
March 2	7.2	7.4	1.20	7.5

Discharge measurements of canals in Umatilla River Valley, Oregon, in 1906—Cont'd.

WILSON & CO.'S CANAL, ECHO.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
February 8	7.6	4.6	2.72	4.2
May 4	7.1	3.2	1.58	2.6

ALLEN CANAL, ECHO.

Date.	Width.	Area of section.	Gage height.	Discharge.
1905.				
December 28	10.2	16	1.24	14
1906.				
January 5	10.2	16	1.25	13
January 17	10.3	16	1.25	12
March 2	9.7	6.9	....	2.8
May 5	10.7	17	1.15	29

ALLEN CANAL WASTEWAY, ECHO.

Date.	Width.	Area of section.	Gage height.	Discharge.
January 5	5.2	4.7	0.75	7.3
January 17 [a]	5.5	6.0	....	10
February 9	5.2	3.7	.52	3.14
February 17	3.6	2.2	.30	.47
March 2	3.5	2.4	.28	.44
May 5	3.6	2.5	.29	.7

HINKLE CANAL, ECHO.

Date.	Width.	Area of section.	Gage height.	Discharge.
January 5	14	14	1.70	14
January 13	13.8	14	1.70	15
January 17	14.4	14	1.71	15
February 8	15	16	1.91	20
February 17	12	11	1.50	9.3
March 2	12.7	13	1.73	14
May 5	16	25	2.43	42

PIONEER CANAL, ECHO.

Date.	Width.	Area of section.	Gage height.	Discharge.
January 5	8.2	3.4	0.80	2.2
January 17	9.7	5.1	.98	4.33
May 5	12.4	23	1.58	54

HERMISTON CANAL, HERMISTON.

Date.	Width.	Area of section.	Gage height.	Discharge.
1905.				
December 28	15.3	14	....	11
1906.				
January 15 [b]	15.4	15	....	11
February 16 [c]	16.0	17	0.62	17
May 7	19.0	29	1.34	39

BEITLE CANAL, HERMISTON.

Date.	Width.	Area of section.	Gage height.	Discharge.
May 7	3.7	1.8	0.92	1.4

OREGON LAND AND WATER COMPANYS CANAL, UMATILLA.

Date.	Width.	Area of section.	Gage height.	Discharge.
May 7	13.5	19	....	44
November 25	4.8	4.1	....	13

[a] Measured above wasteway. [b] At headgate. [c] Below headgate.

Discharge measursmente of canals in Umatilla River Valley. Oregon, in 1906.—Cont'd.

BROWNELL CANAL, HERMISTON.

Date.	Width.	Area of section.	Gage height.	Discharge.
1905.	*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
December 29	5	2.8	0.98	0.97
1906.				
January 15	5	4.3	1.72	4.0
May 7	5	6.4	1.58	10

MAXWELL CANAL, ECHO.

January 5	5.2	1.6	0.31	0.79
January 15	5.4	2.0	.30	1.0
May 3	10.4	8.4		15

WILLOW CREEK DRAINAGE BASIN.

DESCRIPTION OF BASIN.

This stream rises in the timbered foothills of the Blue Mountains and flows northwestward into Columbia River near Arlington. Its drainage area throughout is timberless, and is composed of high, rolling table-lands used for the production of wheat and as range for cattle and sheep. The creek is small but is subject to excessive and sudden floods. In 1903 this stream was the scene of the disaster at Heppner, where over one hundred lives were lost from a sudden flood lasting scarcely more than an hour. The waters of this stream are used to some extent for irrigation in the immediate valley.

WILLOW CREEK NEAR ARLINGTON, OREG.

This station was established December 17, 1904, and was abandoned July 21, 1906, on account of poor conditions. It is located at the wagon bridge at Rhea siding, 9 miles from Arlington, Oreg. The station was maintained as a flood station and miscellaneous measurements only are made during the summer season.

During 1906 the gage was read by G. R. Huff. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 202.

Discharge measurements of Willow Creek near Arlington, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
February 7	F. C. Dillard	24	85	(a)	33
February 28	R. S. Hall	23.5	51	1.50	55
March 31	F. C. Dillard	26	107	(a)	207
April 19	J. C. Stevens	23.5	41	1.12	32
June 9	R. S. Hall	24.5	89	3.15	296
June 9	do	24	94	3.40	363

[a] Gage not read.

Daily gage height, in feet, of Willow Creek near Arlington, Oreg., for 1906.

Day.	Mar.	Apr.	May.	June.	July.	Day.	Mar.	Apr.	May.	June.	July.
1	1.52	2.8	0.85	4.4	1.15	17	1.35	1.25	0.45	2.4	0.8
2	1.52	2.7	.8	3.9	1.1	18	1.6	1.2	.45	2.2	.8
3	1.5	2.5	.75	3.65	1.0	19	1.5	1.15	.45	2.0	.8
4	1.52	2.4	.65	3.9	.95	20	1.45	1.1	.45	1.9	.8
5	1.55	2.3	.6	4.05	.95	21	1.4	1.1	.45	1.8	.8
6	1.5	2.2	.6	3.75	.95	22	1.98	1.1	.45	1.6	....
7	1.52	2.1	.6	3.5	.95	23	2.45	1.1	.45	1.5	....
8	1.62	2.0	.6	3.2	.9	24	2.3	1.1	.45	1.4	....
9	1.75	1.9	.55	3.0	.85	25	2.4	1.1	.5	1.35	....
10	1.8	1.8	.5	3.1	.85	26	4.15	1.1	.5	1.25	....
11	1.8	1.7	.5	2.8	.9	27	3.0	1.0	.6	1.2	....
12	1.75	1.6	.45	2.6	.9	28	3.1	1.0	.55	1.2	....
13	1.8	1.5	.45	2.6	.9	29	2.7	.9	.5	1.2	....
14	1.8	1.4	.45	2.45	.85	30	2.4	.9	6.7	1.15	....
15	1.75	1.35	.4	2.3	.8	31	2.4	....	6.0	....	....
16	1.35	1.3	.45	3.1	.8						

Note.—Some ice March 12 and 13; discharge not corrected.

Rating table for Willow Creek near Arlington, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.40	10	1.20	35	2.00	100	2.80	224	3.60	421
0.50	12	1.30	41	2.10	112	2.90	244	3.70	454
0.60	14	1.40	48	2.20	125	3.00	265	3.80	489
0.70	16	1.50	55	2.30	139	3.10	286	3.90	526
0.80	19	1.60	63	2.40	154	3.20	309	4.00	565
0.90	22	1.70	72	2.50	170	3.30	334	5.00	965
1.00	25	1.80	81	2.60	187	3.40	361	6.00	1,365
1.10	30	1.90	90	2.70	205	3.50	390	7.00	1,765

Note.—The above table is applicable only for open-channel conditions. It is based on 4 discharge measurements made during 1906 and is not well defined.

Monthly discharge of Willow Creek near Arlington, Oreg., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
March	625	44	115	7,070
April	224	22	71.1	4,230
May	1,640	10	109	6,700
June	725	32	221	13,200
July 1-21	32	19	22.1	920
The period	....	....	....	32,100

Note.—Values are rated as follows: May, approximate; remainder of period, fair.

JOHN DAY RIVER DRAINAGE BASIN.

JOHN DAY RIVER AT M'DONALD, OREG.

John Day River rises in the Blue Mountains in northeastern Oregon, at an elevation of about 5,000 feet, and flows northward into Columbia River. The lower 90 miles of the stream flows in a comparatively deep canyon from which it is impracticable to take water for irrigation. The surrounding country is rolling, timberless land, partly cultivated and partly desert. The upper portions of the stream are more broken and mountainous, and large areas are well timbered. The river is fed by innumerable tributaries draining timbered mountain slopes. The main stream is formed by the junction of three important streams called North, Middle, and South forks of John Day River. The rainfall in the drainage area varies from 25 inches on the headwaters to 9 inches at the mouth of the river.

The waters of the numerous mountain tributaries are used extensively for irrigating small valleys, for mining, and for power purposes. Irrigation is not practiced in the lower portion of the stream to any considerable extent.

This station was established November 14, 1901. It is located at the ferry at McDonald, 16 miles above the mouth of the river and 18 miles southwest of Arlington, Oreg. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 203, where are given also references to publications that contain data for previous years.

Discharge measurements of John Day River at McDonald, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
February 6	F. C. Dillard	263	728	2.35	[illegible]
February 23	R. S. Hall	282	1,140	3.88	2,940
March 15	do	273	910	3.10	1,710
April 2	F. C. Dillard	319	2,050	6.70	10,500
April 17	J. C. Stevens	314	1,640	5.50	6,840
May 2	R. S. Hall	309	1,430	4.70	4,700
June 8	do	322	1,860	6.16	8,670
July 6	do	278	797	2.69	1,240
November 23	H. McGlashan	268	624	1.97	495

Daily gage height, in feet, of John Day River at McDonald, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.80	2.40	3.80	7.50	4.70	6.98	3.22	1.55	1.45	1.55	1.75	1.70
2	1.90	2.52	3.55	6.72	4.68	6.48	3.08	1.55	1.45	1.55	1.75	1.80
3	1.85	2.58	3.25	6.05	4.62	6.20	2.98	1.55	1.40	1.55	1.75	1.80
4	1.78	2.42	3.15	5.45	4.58	6.10	2.88	1.50	1.40	1.55	1.75	1.85
5	1.80	2.42	3.10	5.35	4.52	6.78	2.78	1.50	1.40	1.55	1.75	1.85
6	1.85	2.35	3.10	5.45	4.55	6.82	2.68	1.50	1.40	1.55	1.75	1.92
7	1.88	2.35	3.05	5.60	4.35	6.55	2.60	1.50	1.40	1.55	1.72	1.95
8	1.90	2.30	3.15	6.00	4.15	6.15	2.50	1.50	1.40	1.55	1.82	2.00
9	1.85	2.20	3.75	5.92	4.05	5.80	2.48	1.45	1.40	1.60	1.85	2.00
10	1.90	2.15	4.15	5.90	3.98	5.70	2.42	1.45	1.35	1.60	1.85	2.10
11	1.90	2.20	4.50	5.85	3.92	5.45	2.42	1.45	1.35	1.60	1.85	2.20
12	1.90	2.18	4.25	5.55	3.98	5.25	2.32	1.45	1.40	1.60	1.92	2.20
13	1.88	2.12	4.75	5.25	3.98	5.05	2.28	1.45	1.40	1.60	2.00	2.15
14	1.90	2.12	3.40	5.05	4.00	4.95	2.20	1.40	1.45	1.60	1.95	2.18
15	1.90	2.20	3.15	5.00	3.80	4.72	2.12	1.82	1.45	1.60	2.00	2.28
16	2.00	2.20	3.10	5.12	3.70	4.55	2.05	1.88	1.45	1.60	1.95	2.20
17	2.00	2.20	3.00	5.35	3.80	4.60	2.00	1.70	1.52	1.60	2.00	2.15
18	2.10	2.28	2.90	5.60	3.65	4.72	2.00	1.65	1.65	1.60	2.40	2.10
19	2.30	2.30	2.95	5.35	3.50	4.50	1.92	1.60	1.75	1.65	2.30	2.00
20	2.18	3.35	3.00	5.12	3.40	4.15	1.90	1.60	1.75	1.65	2.22	2.10
21	2.10	3.88	3.00	5.10	3.28	4.00	1.90	1.50	1.70	1.70	2.20	2.10
22	2.05	3.70	3.00	5.25	3.25	3.88	1.85	1.50	1.70	1.70	2.10	2.20
23	2.00	3.85	3.35	5.60	3.30	3.78	1.80	1.50	1.70	1.70	2.00	2.25
24	2.25	3.50	4.55	5.60	3.40	3.60	1.80	1.45	1.65	1.70	2.00	2.55
25	2.60	3.25	5.05	5.50	3.40	3.50	1.75	1.45	1.60	1.75	2.10	2.65
26	2.95	3.20	6.55	5.35	3.30	3.40	1.70	1.45	1.60	1.75	2.00	2.75
27	2.92	3.10	6.40	5.22	3.40	3.45	1.70	1.45	1.60	1.75	1.95	3.00
28	2.80	3.10	6.55	5.00	3.40	3.30	1.65	1.48	1.60	1.75	1.90	4.10
29	2.58	......	6.30	4.85	3.50	3.35	1.60	1.50	1.60	1.75	1.95	3.75
30	2.50	......	6.10	4.72	3.50	3.40	1.60	1.50	1.60	1.75	1.90	3.45
31	2.42	......	6.50	......	7.85	......	1.60	1.50	......	1.75	......	3.25

Rating table for John Day River at McDonald, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.00	60	2.00	540	3.00	1,615	3.90	3,050	5.60	7,050
1.10	85	2.10	625	3.10	1,750	4.00	3,240	5.80	7,590
1.20	115	2.20	715	3.20	1,890	4.20	3,650	6.00	8,150
1.30	145	2.30	810	3.30	2,035	4.40	4,090	6.20	8,710
1.40	180	2.40	910	3.40	2,185	4.60	4,550	6.40	9,290
1.50	220	2.50	1,015	3.50	2,345	4.80	5,020	6.60	9,880
1.60	265	2.60	1,125	3.60	2,515	5.00	5,500	6.80	10,480
1.70	320	2.70	1,240	3.70	2,690	5.20	6,000	7.00	11,100
1.80	385	2.80	1,360	3.80	2,870	5.40	6,520	8.00	14,310
1.90	460	2.90	1,485						

Note.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905-6 and is well defined below gage height 6.0 feet.

Monthly discharge of John Day River at McDonald, Oreg., for 1906.

[Drainage area, 7,800 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	1,550	372	672	41,300	0.086	0.10
February	3,010	643	1,280	71,100	.164	.17
March	9,730	1,480	3,820	235,000	.490	.56
April	12,700	4,830	6,860	408,000	.879	.98
May	13,800	1,960	3,390	208,000	.435	.50
June	11,000	2,040	5,560	331,000	.713	.80
July	1,920	265	760	46,700	.097	.11
August	445	180	236	14,500	.030	.03
September	352	162	234	13,900	.030	.03
October	352	242	288	17,700	.037	.04
November	910	352	506	30,100	.065	.07
December	3,440	320	969	59,600	.124	.14
The year	13,800	162	2,050	1,480,000	.262	3.53

Note.—Values are rated as excellent.

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made in John Day River drainage basin in 1906:

Canyon Creek at Canyon City, Oreg.—The reference point is a cross cut in the top of a cap of a bent on the right bank downstream side of the highway bridge.

July 2, width, 27 feet; area, 22 square feet; gage height, −8.00 feet; discharge, 50 second-feet.

Rock Creek at Rockcreek, Oreg.—Rockcreek is a station on the Oregon Railroad and Navigation Company's Condon branch, 6 miles above the mouth of the creek. Measurements are made at a highway bridge near the railway station. The reference point is on top of the first projecting beam from the left bank on upstream side of the bridge; elevation, 15 feet above the datum of the assumed gage.

February 6, width, 24 feet; area, 33 square feet; gage height, 5.67 feet; discharge, 35 second-feet.

February 23 width, 40 feet; area, 62 square feet; gage height, 6.48 feet; discharge, 122 second-feet.

March 16, width, 30 feet; area, 53 square feet; gage height, 6.07 feet; discharge, 87 second-feet.

DESCHUTES RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Deschutes River and its tributaries drain the eastern slope of the Cascade Mountains in Oregon. The main stream flows northward parallel to this range and empties into Columbia River 15 miles above The Dalles. Its drainage area may be divided into two parts: The tributaries from the west drain the timbered slopes of the Cascade Range; those from the east drain the timberless areas of high table-lands which are devoted largely to the production of wheat and to ranges for sheep and cattle. The soil throughout is composed of disintegrated lava rock, interlaid with porous lava and basalt, a fact which no doubt accounts for the remarkable constancy in the flow of this river and its tributaries from the west. The maximum discharge is only about four times the minimum. The stream is therefore the most valuable in the State. Its power possibilities are phenomenal, and its upper portions furnish an abundance of water for the irrigation of the fertile table-lands. Its principal tributaries are West Fork, Tumalo Creek, Squaw Creek, Crooked River, Metolius River, Warm Springs, and White River, all of which are used for irrigation, power, and logging purposes.

DESCHUTES RIVER NEAR LAVA, OREG.

This station was established February 17, 1905, about 1 mile north of Lava, Oreg. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 212.

Discharge measurements of Deschutes River near Lava, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 14	I. Landes	56.5	181	6.21	317
May 1	do	66.5	231	6.96	422
May 12	do	67.0	248	7.15	485
June 12	do	56.0	215	6.94	413
June 21	J. C. Stevens	61.0	210	6.67	365

Daily gage height, in feet, of Deschutes River near Lava, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5.4	5.7	5.3	5.6	7.0	6.65	6.45	5.5	5.2	5.15	5.1	5.45
2	5.35	5.7	5.2	5.6	6.9	6.6	6.4	5.5	5.15	5.15	5.1	5.35
3	5.35	5.7	5.25	5.65	6.9	6.7	6.3	5.5	5.15	5.15	5.1	5.4
4	5.35	5.5	5.2	5.6	6.9	6.65	6.3	5.5	5.15	5.15	5.1	5.45
5	5.45	5.45	5.25	5.7	6.95	6.6	6.35	5.5	5.15	5.15	5.2	5.45
6	5.5	5.4	5.2	5.85	7.0	6.85	6.35	5.45	5.15	5.15	5.3	5.4
7	5.5	5.4	5.2	6.0	7.05	7.0	6.35	5.45	5.15	5.15	5.3	5.4
8	5.5	5.45	5.3	6.1	7.1	7.0	6.35	5.45	5.15	5.15	5.35	5.45
9	5.5	5.4	5.25	6.15	7.15	7.05	6.35	5.4	5.2	5.1	5.65	5.45
10	5.5	5.35	5.2	6.2	7.15	7.1	6.3	5.4	5.2	5.1	5.65	5.4

Daily gage height, in feet, of Deschutes River near Lava, Oreg., for 1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
11	5.6	5.3	5.35	6.25	7.15	7.15	6.2	5.4	5.25	5.1	5.6	5.4
12	5.6	5.25	5.65	6.25	7.15	7.0	6.2	5.5	5.25	5.15	5.55	5.7
13	5.6	5.15	5.75	6.2	7.2	6.95	6.2	5.45	5.3	5.15	5.0	5.4
14	5.6	5.1	5.5	6.25	7.25	6.85	6.2	5.4	5.3	5.2	5.55	5.3
15	5.6	5.15	5.5	6.35	7.35	6.85	6.15	5.4	5.35	5.2	5.55	5.45
16	5.75	5.15	5.5	6.5	7.35	6.85	6.15	5.4	5.3	5.2	5.65	5.4
17	5.75	5.1	5.55	6.65	7.35	6.85	6.1	5.35	5.3	5.3	5.9	5.35
18	5.8	5.15	5.5	6.82	7.4	6.85	6.1	5.3	5.3	5.3	5.9	5.4
19	5.7	5.65	5.5	6.9	7.35	6.8	6.1	5.3	5.3	5.3	5.9	5.45
20	5.85	5.4	5.5	6.9	7.1	6.75	5.95	5.3	5.25	5.25	5.85	5.5
21	5.9	5.3	5.5	6.95	6.95	6.7	5.95	5.3	5.2	5.2	5.85	5.65
22	5.95	5.35	5.55	7.05	6.8	6.6	5.85	5.3	5.2	5.2	5.8	5.7
23	5.95	5.4	5.7	7.18	6.75	6.55	5.8	5.35	5.2	5.15	5.7	5.65
24	5.95	5.45	5.6	7.28	6.65	6.5	5.75	5.3	5.2	5.15	5.45	5.75
25	6.1	5.4	5.75	7.35	6.65	6.45	5.75	5.3	5.2	5.15	5.45	5.85
26	6.1	5.3	5.7	7.35	6.6	6.5	5.7	5.3	5.2	5.1	5.45	5.85
27	6.1	5.3	5.6	7.35	6.6	6.5	5.65	5.25	5.2	5.1	5.45	5.9
28	6.1	5.4	5.7	7.25	6.8	6.45	5.65	5.25	5.2	5.1	5.45	6.0
29	6.1	....	5.7	7.2	6.85	6.45	5.65	5.2	5.2	5.1	5.45	5.9
30	5.9	....	5.8	7.1	7.0	6.45	5.6	5.2	5.2	5.1	5.45	5.8
31	5.9	....	5.85	....	7.05	....	5.55	5.2	....	5.1	....	5.8

Note.—From January 1 to March 22 there was some obstruction from ice, which formed and then went out again, sometimes reaching a thickness of 0.6 foot. There was also some ice November 23 to December 8. Discharges have been applied as for open channel.

Rating table for Deschutes River near Lava, Oreg., for 1905–6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
4.80	76	5.40	125	6.00	205	6.60	329	7.20	498
4.90	82	5.50	135	6.10	223	6.70	355	7.30	528
5.00	89	5.60	147	6.20	242	6.80	382	7.40	559
5.10	97	5.70	160	6.30	262	6.90	410		
5.20	106	5.80	173	6.40	283	7.00	439		
5.30	115	5.90	188	6.50	305	7.10	468		

Note.—The above table is applicable only for open-channel conditions. It is based on 11 discharge measurements made during 1905–6 and is well defined between gage heights 6.0 feet and 7.5 feet. Below gage height 6 feet the measurements are inconsistent.

Monthly discharge of Deschutes River near Lava, Oreg., for 1906.

[Drainage area. 880 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	223	120	166	10,200	0.189	0.22
February	160	97	123	6,830	.140	.15
March	180	106	136	8,360	.155	.18
April	544	147	332	19,800	.377	.42
May	559	329	445	27,400	.506	.58
June	483	294	369	22,000	.419	.47
July	294	141	220	13,500	.250	.29
August	135	106	122	7,500	.139	.16
September	120	102	108	6,430	.123	.14
October	115	97	103	6,330	.117	.13
November	188	89	137	8,150	.156	.17
December	205	115	144	8,850	.164	.19
The year	559	89	200	145,000	.228	3.10

Note.—Values are rated as fair.

DESCHUTES RIVER AT WEST'S RANCH, NEAR LAVA, OREG.

This station was established June 20, 1906. It is located at a private bridge on B. F. West's ranch, 16 miles above Bend. It is below the mouth of West Fork and of Spring River and above all important diversions.

The channel is straight for 200 feet above and 100 feet below the station. The right bank is low, sparsely wooded, and liable to overflow at rare intervals; the left is high and rocky and will not overflow. The bed of the stream is partly of rock and partly of gravel, and will change only during floods.

Measurements are made from a private highway bridge constructed of logs. The initial point is a mark on the guardlog of the bridge, nearly over the gage.

The gage, which is read by B. F. West, is a 2 by 4 inch timber spiked to the approach on the right bank. The bench mark is a spike in the north side of the base of a lone yellow pine, 75 feet upstream from the bridge on the left bank; elevation, 17.44 feet above the datum of the gage.

Discharge measurements of Deschutes River at West's ranch, near Lava, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 13	I. Landes	107	588	9.08	1,580
May 20	do	110	652	9.42	1,930
June 12	do	110	649	9.39	1,910
June 20	Stevens and Landes	110	626	9.30	1,780
August 23	C. W. Allen	105	576	8.85	1,400

Daily gage height, in feet, of Deschutes River at West's ranch, near Lava, Oreg., for 1906.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		8.9	8.8	8.8	8.7	8.75	17		8.85	8.85	8.75	8.95	8.8
2		8.9	8.8	8.8	8.7	8.75	18		8.85	8.85	8.75	9.0	8.8
3		8.9	8.8	8.8	8.7	8.75	19		8.85	8.85	8.75	8.95	8.85
4		8.9	8.8	8.8	8.7	8.75	20		8.85	8.8	8.75	8.9	8.85
5		8.9	8.8	8.75	8.75	8.75	21	9.0	8.85	8.8	8.75	8.9	8.85
6		8.9	8.8	8.75	8.75	8.75	22	9.0	8.85	8.8	8.75	8.9	8.9
7		8.9	8.8	8.75	8.8	8.8	23	8.98	8.85	8.8	8.7	8.8	8.9
8		8.9	8.8	8.75	8.8	8.8	24	8.95	8.85	8.8	8.7	8.8	8.9
9		8.9	8.8	8.75	8.8	8.8	25	8.95	8.85	8.8	8.7	8.82	8.9
10		8.9	8.8	8.75	8.88	8.8	26	8.95	8.85	8.8	8.7	8.75	8.98
11		8.9	8.8	8.75	8.85	8.8	27	8.95	8.85	8.8	8.7	8.7	9.0
12		8.9	8.8	8.78	8.85	8.75	28	8.95	8.85	8.8	8.7	8.72	9.0
13		8.9	8.82	8.75	8.8	8.75	29	8.95	8.8	8.8	8.7	8.72	8.95
14		8.9	8.85	8.75	8.8	8.8	30	8.92	8.8	8.8	8.7	8.75	8.95
15		8.85	8.85	8.75	8.85	8.8	31	8.90	8.8		8.7		8.9
16		8.85	8.85	8.75	8.9	8.78							

Rating table for Deschutes River at West's ranch, near Lava, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
8.70	1,290	8.90	1,430	9.10	1,590	9.30	1,780	9.40	1,900
8.80	1,360	9.00	1,510	9.20	1,680				

NOTE.—The above table is applicable only for open-channel conditions. It is based on 5 discharge measurements made during 1906 and is well defined.

Monthly discharge of Deschutes River at West's ranch, near Lava, Oreg., for 1906.

[Drainage area, 1,240 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
July 21-31	1,510	1,430	1,470	32,100	1.19	0.49
August	1,430	1,360	1,410	86,700	1.14	1.31
September	1,400	1,360	1,370	81,500	1.10	1.23
October	1,360	1,290	1,320	81,200	1.06	1.22
November	1,510	1,290	1,370	81,500	1.10	1.23
December	1,510	1,320	1,390	85,500	1.12	1.29
The period				448,000		

NOTE.—Values are rated as excellent.

DESCHUTES RIVER AT BEND, OREG.

This station was established December 22, 1904. It is located at the wagon bridge known as Sizemore's bridge, 1½ miles south of Bend, Oreg.

On account of backwater from logs and other disturbing influences the gage heights at this station are no index of the discharge, which is practically the same as at West's ranch. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 208, where are given also references to publications that contain data for previous years.

Discharge measurements of Deschutes River at Bend, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 19	I. Landes	370.5	747	1.78	1,680
June 19	J. C. Stevens	376	883	2.11	1,880

DESCHUTES RIVER NEAR BIGGS, OREG.

This station was established July 7, 1906. It is located at Taylor's ranch, 1½ miles above the junction of the river with the Columbia, about the same distance above the Oregon Railroad and Navigation Company's bridge, and 1 mile above Moody's toll bridge.

The channel is straight; the banks are overgrown with alder and not liable to overflow. The bed of the stream is of rock and gravel, free from vegetation, and liable to shift slightly. There is but one channel at all stages. There is a good even current at the gaging section; a little lower down it is considerably broken by falls and riffles.

Measurements are made from a car and cable of 490 feet span. The initial point for soundings is 8 feet from the inside of the shear leg on the left bank. There is a tagged wire overhead and a stay-line 100 feet upstream.

The gage, which is read by Wilbur Taylor, is 150 yards below the point of measurement, on the right bank. It is in two sections and is bolted to alder trees. The bench mark is the top of three 20-penny nails driven into the trunk of the alder tree to which the lower part of the gage is anchored; elevation, 5.46 feet above the datum of the gage.

Discharge measurements of Deschutes River near Biggs, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
July 7	L. R. Allen	452	1,610	2.63	6,010
August 30	do	449	1,550	2.34	5,140
September 29	I. E. Oakes	435	1,530	2.30	5,000
October 18	Stevens and Oakes	450	1,530	2.35	5,320
December 17	H. D. McGlashan	449	1,650	2.64	5,710

Daily gage height, in feet, of Deschutes River near Biggs, Oreg., for 1906.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		2.4	2.3	2.3	2.35	2.56	17		2.4	2.3	2.3	3.6	2.63
2		2.4	2.3	2.3	2.35		18		2.4	2.3	2.35	3.46	
3		2.4	2.3	2.3	2.35	2.55	19		2.4	2.3	2.35		2.65
4		2.4	2.3	2.3	2.35		20		2.4	2.3	2.35	3.1	
5		2.4	2.3	2.3	2.35	2.55	21		2.4	2.3	2.35	2.85	3.5
6		2.4	2.3	2.3	2.35	2.55	22	2.4	2.4	2.3	2.35	2.75	3.25
7		2.4	2.3	2.3	2.45		23	2.4	2.4	2.3	2.35		
8		2.4	2.3	2.3	3.25	2.66	24	2.4	2.4	2.3	2.35	2.7	3.18
9		2.4	2.3	2.3			25	2.4	2.4	2.3	2.35		3.1
10		2.4	2.3	2.3	2.9	2.62	26	2.4	2.4	2.3	2.35	2.65	
11		2.4	2.3	2.3	3.0	2.6	27	2.4	2.4	2.3	2.56		3.08
12		2.4	2.3	2.3			28	2.4	2.4	2.3	2.4	2.6	
13		2.4	2.3	2.3	3.8	2.58	29	2.4	2.4	2.3	2.39		3.03
14		2.4	2.3	2.3	3.65		30	2.4	2.4	2.3	2.36	2.58	3.0
15		2.4	2.3	2.3	4.1	2.55	31	2.4	2.4		2.35		2.98
16		2.4	2.3	2.3	3.9								

Rating table for Deschutes River near Biggs, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.30	5,140	2.70	6,060	3.10	7,020	3.50	8,000	3.90	9,000
2.40	5,370	2.80	6,300	3.20	7,260	3.60	8,250	4.00	9,250
2.50	5,600	2.90	6,540	3.30	7,500	3.70	8,500	4.10	9,500
2.60	5,830	3.00	6,780	3.40	7,750	3.80	8,750		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 5 discharge measurements made during 1906 and is fairly well defined below gage height 2.7 feet.

Monthly discharge of Deschutes River near Biggs, Oreg., for 1906.

[Drainage area, 9,180 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
July 22-31	5,370	5,370	5,370	106,000	0.585	0.22
August	5,370	5,370	5,370	330,000	.585	.67
September	5,140	5,140	5,140	306,000	.560	.62
October	5,740	5,140	5,220	321,000	.569	.66
November	9,500	5,260	6,640	395,000	.723	.81
December	8,000	5,720	6,360	391,000	.693	.80
The period				1,850,000		

NOTE.—Values are rated as fair.

EAST FORK OF DESCHUTES RIVER AT ODELL, OREG.

This station was established December 25, 1904, at Odell post-office. The conditions and the bench marks are described in Water-Supply Paper No. 178, page 210, where are given also references to publications that contain data for previous years.

Discharge measurements of East Fork of Deschutes River at Odell, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 11	I. Landes	24	34	2.70	63
May 21	do	25	43	3.15	101
June 14	do	25.5	47	[a]3.40	118
June 21	Stevens and Landes	25.5	44	3.15	109

[a] Gage height uncertain.

Daily gage height, in feet, of East Fork of Deschutes River at Odell, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.1	3.2	3.1	2.6	3.25	3.1	3.0	2.4	2.2	2.2	2.2	2.75
2	3.1	3.2	2.7	2.6	3.25	3.1	3.0	2.4	2.2	2.2	2.2	2.65
3	3.0	3.2	3.05	2.92	3.3	3.1	2.9	2.4	2.2	2.2	2.2	2.7
4	3.0	2.8	3.1	2.6	3.35	3.2	3.0	2.3	2.2	2.2	2.3	2.75
5	3.0	2.8	3.0	2.55	3.4	3.3	3.1	2.3	2.2	2.2	2.3	2.5
6	3.0	3.1	2.9	2.75	3.5	3.4	3.1	2.3	2.5	2.2	2.4	2.5
7	3.0	2.9	2.9	2.5	3.5	3.3	3.0	2.2	2.5	2.2	2.6	2.5
8	3.0	2.9	3.0	2.8	3.45	3.3	2.9	2.2	2.5	2.2	2.4	2.5
9	3.0	2.8	2.9	2.85	3.5	3.3	2.8	2.2	2.5	2.2	2.4	2.5
10	2.8	2.9	2.85	2.85	3.55	3.2	2.8	2.2	2.5	2.2	2.4	2.5
11	2.8	3.0	2.9	2.7	3.55	3.2	2.75	2.2	2.5	2.2	2.65	2.7
12	2.8	3.1	2.8	2.7	3.6	3.3	2.75	2.3	2.5	2.2	2.65	2.6
13	2.9	3.1	2.5	2.75	3.6	3.3	2.7	2.3	2.3	2.2	2.65	2.5
14	2.9	3.1	3.0	2.8	3.7	3.4	2.7	2.3	2.4	2.2	2.65	2.5
15	3.1	3.0	2.9	2.9	3.7	3.4	2.7	2.3	2.4	2.2	2.4	2.4
16	3.1	3.0	2.8	3.0	3.6	3.5	2.7	2.3	2.3	2.2	2.7	2.5
17	2.4	3.1	2.7	3.0	3.4	3.5	2.7	2.3	2.3	2.65	2.6	2.5
18	2.2	3.2	2.7	3.0	3.3	3.4	2.7	2.3	2.3	2.3	2.65	2.5
19	2.2	3.2	2.8	3.0	3.1	3.2	2.6	2.3	2.3	2.3	2.4	2.6
20	2.18	3.35	2.8	3.0	3.0	3.1	2.6	2.3	2.2	2.3	2.6	2.5
21	3.5	3.5	2.8	3.3	3.1	3.1	2.65	2.3	2.2	2.65	2.6	2.5
22	3.0	3.3	2.85	3.4	3.1	3.1	2.5	2.3	2.2	2.65	2.55	2.45
23	3.4	3.3	3.2	3.4	2.9	3.1	2.5	2.3	2.2	2.65	2.5	2.4
24	3.4	3.0	3.1	3.4	2.9	3.0	2.5	2.5	2.2	2.65	2.68	2.45
25	3.4	2.85	3.1	3.45	2.9	3.0	2.5	2.5	2.2	2.2	2.65	2.5
26	3.4	2.85	3.0	3.3	3.0	3.0	2.45	2.5	2.2	2.2	2.85	2.7
27	2.9	2.8	3.0	3.25	3.0	3.0	2.45	2.5	2.2	2.2	2.85	2.6
28	3.2	3.25	2.75	3.25	3.3	3.0	2.45	2.5	2.2	2.2	2.65	2.5
29	3.2	....	2.65	3.2	3.2	3.0	2.45	2.2	2.2	2.2	2.7	2.5
30	3.2	....	2.7	3.25	3.2	3.0	2.4	2.2	2.2	2.2	2.65	2.5
31	3.2	....	3.1	....	3.1	....	2.4	2.2	....	2.2	....	2.4

Rating table for East Fork of Deschutes River at Odell, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.10	24	2.50	49	2.90	81	3.30	121	3.70	174
2.20	30	2.60	56	3.00	90	3.40	133		
2.30	36	2.70	64	3.10	100	3.50	146		
2.40	42	2.80	72	3.20	110	3.60	160		

Note.—The above table is applicable only for open-channel conditions. It is based on 3 discharge measurements made during 1906 and the form of previous curves and is fairly well defined.

Monthly discharge of East Fork of Deschutes River at Odell, Oreg., for 1906.

[Drainage area, 196 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	146	29	88.8	5,460	0.454	0.52
February	146	72	97.6	5,420	.498	.52
March	110	60	80.8	4,970	.413	.48
April	140	49	89.7	5,340	.458	.51
May	174	81	124	7,620	.633	.73
June	146	90	110	6,540	.562	.63
July	100	42	65.2	4,010	.333	.38
August	49	30	37.8	2,320	.196	.23
September	49	30	36.2	2,150	.185	.21
October	60	30	35.4	2,180	.182	.21
November	77	30	52.0	3,090	.265	.30
December	68	42	52.0	3,200	.265	.31
The year	174	29	73.0	52,300	.522	5.03

NOTE.—Values are rated as fair.

WEST FORK OF DESCHUTES RIVER NEAR LAVA, OREG.

This station was established February 20, 1905, about 1½ miles west of Lava, Oreg. The conditions and the bench marks are described in Water-Supply Paper No. 178, page 214, where are given also references to publications that contain data for previous years.

Discharge measurements of West Fork of Deschutes River near Lava, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 13	I. Landes	99	453	7.91	910
May 2	do	100	468	8.10	880
May 13	do	100	485	8.30	942
June 11	do	101	485	8.39	955
June 21	Stevens and Landes	101	484	8.26	914

Daily gage height, in feet, of West Fork of Deschutes River near Lava, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		7.52						8.05				
2	8.01	7.50								8.10	7.90	
3		7.50	7.50									
4	7.70	7.50					8.15					
5	7.62	7.50			8.50	8.35		8.10		8.00		
6	7.62	7.50										
7	7.65	7.50		7.80					8.01			
8	7.60	7.50			8.15							8.10
9	7.60	7.50								8.00	8.00	
10	7.60	7.50	7.60									
11	7.60	7.50					8.15				8.00	
12	7.60	7.50				8.40		8.15		8.10	7.90	
13	7.70	7.50			8.30							
14	7.65	7.50		8.00					8.20			
15	7.65	7.50										7.90
16	7.85	7.50								8.10	8.10	
17	7.62	7.55	7.40		8.40							
18	7.70	7.62					8.15					
19	7.66	7.70						8.10		8.00		
20	7.60	7.65			8.30							

Daily gage height. in feet, of West Fork of Deschutes River near Lava, Oreg., in 1906— Continued.

Day.	Jan.	Feb.	Mar.	Apr	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
21	7.55	7.60				8.26			8.01			
22	7.60	7.60										7.70
23	7.65	7.60										
24	7.66	7.60	7.50			8.20	8.10				7.95	
25	7.60	7.60										
26	7.60					8.25		8.15		7.95		
27	7.58											
28	7.55	7.50		8.20					8.01			
29	7.55											8.00
30	7.55										7.90	
31	7.55		7.75					8.15				

Note.—There was some floating ice during January.

Rating tables for West Fork of Deschutes River near Lava, Oreg.

JANUARY 1, 1905, TO APRIL 30, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
7.40	837	7.60	867	7.80	902	8.00	942	8.20	984
7.50	852	7.70	883	7.90	922	8.10	963		

MAY 1 TO DECEMBER 31, 1906.[b]

7.50	727	7.80	802	8.10	879	8.40	958	8.50	985
7.60	752	7.90	827	8.20	905				
7.70	777	8.00	853	8.30	931				

[a] This table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905–6 and is well defined above gage height, 7.7 feet.

[b] This table is applicable only for open-channel conditions. It is based on 4 discharges measurements made during 1906 and is well defined above gage height 8.1 feet. The table has been extended beyond these limits.

Monthly discharge of West Fork of Deschutes River near Lava, Oreg., for 1906.

[Drainage area, 360 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
January	944	860	874	53,700	2.43	2.80
February	883	852	858	47,700	2.38	2.48
March	892	837	860	52,900	2.39	2.76
April	984	902	943	56,100	2.62	2.92
May	985	892	939	57,700	2.61	3.01
June	958	905	929	55,300	2.58	2.88
July	892	879	889	54,700	2.47	2.85
August	892	866	883	54,300	2.45	2.82
September	905	856	868	51,600	2.41	2.69
October	879	840	862	53,000	2.39	2.76
November	879	827	844	50,200	2.34	2.61
December	879	777	834	51,300	2.32	2.68
The year	985	777	882	638,000	2.45	33.26

Note.—Owing to the steady flow of the river the mean discharge for the days of each month when the gage was read has been taken as the mean for the month. Values are good.

CENTRAL OREGON AND PILOT BUTTE CANALS, NEAR BEND, OREG.

These canals have a common head-gate and are operated by the Deschutes Irrigation and Power Company, under the provisions of the Carey Act. They divert water from Deschutes River about 3 miles above Bend. Measurements are made 2,000 feet below dividing point. The conditions at these stations are described in Water-Supply Paper No. 178, pages 216–217.

Discharge measurements of Central Oregon canal near Bend, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet*	*Sec.-ft.*
April 18	I. Landes	13.3	11	0.80	35
May 18	do	13.3	17	1.25	66
June 10	do	13.3	19	1.45	86
June 19	J. C. Stevens	13.4	19	1.44	92
June 19	I. Landes	13.4	19	1.44	90
June 19	L. R. Allen	13.4	19	1.44	87
August 22	C. W. Allen	13.3	25	1.87	134

Daily gage height, in feet, of Central Oregon canal near Bend, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		1.35	1.25	1.25	.80	1.25	1.58	1.80	1.87	1.84	1.68	1.09
2		1.25	.90	1.25		1.25	1.58	1.80	1.88	1.84	1.65	.96
3	.38	1.60	1.15	1.25	1.12	1.25	1.58	1.80	1.87	1.82	1.59	.98
4	.90	1.60	1.30	1.25	1.30	1.25	1.58	1.80	1.87	1.84	1.08	.96
5	.90	1.20	1.20	1.25	1.20	1.25	1.61	1.80	1.87	1.84	1.09	1.09
6	.90	.95	.60	1.25	1.20	1.25	1.64	1.80	1.87	1.84	1.6	1.19
7	1.00	.65	.60	1.25	.60	1.25	1.64	1.80	1.87	1.84	1.48	1.20
8	.55	.65	.60	1.12	.60	1.35	1.65	1.80	1.86	1.84	1.10	1.20
9		.65	.90	.90	1.20	1.45	1.65	1.80	1.87	1.84	1.02	1.20
10		.65	.90	.82	1.22	1.45	1.67	1.80	1.87	1.84	0.51	1.20
11		.32		.85	1.20	1.45	1.69	1.80	1.87	1.83		1.20
12	.62	.33	.35	1.20	1.20	1.45	1.85	1.80	1.87	1.83		1.20
13	.43	.32	.45	1.25	1.20	1.45	1.84	1.80	1.85	1.84		1.20
14	1.42	.65		1.25	1.20	1.45	1.85	1.80	1.84	1.84	1.00	1.38
15	1.50	1.10		1.25	1.20	1.45	1.85	1.80	1.84	1.84	1.40	1.54
16	1.20	.65		.62	1.20	1.45	1.77	1.87	1.84	1.82	1.60	1.55
17				.40	1.20	1.45	1.70	1.87	1.84	1.80	1.58	1.55
18				.78	1.20	1.45	1.70	1.87	1.84	1.77		1.55
19				.90	1.20	1.45	1.70	1.87	1.84	1.77	.20	1.55
20				.85	1.10	1.45	1.70	1.87	1.84	1.77	.62	1.55
21				.75	1.10	1.45	1.70	1.87	1.84	1.76	.98	1.55
22				.75	1.10	1.48	1.70	1.87	1.84	1.77	.38	1.55
23				.78	1.10	1.53	1.70	1.87	1.82	1.77	.40	1.55
24				.75	1.10	1.53	1.70	1.87	1.84	1.77	.60	1.38
25	1.50		.55	.80	1.10	1.53	1.70	1.77	1.84	1.76	.77	1.20
26	1.40		1.05	.82	1.10	1.53	1.80	1.77	1.84	1.76	.90	1.20
27	1.25	.50	1.05	.85	1.25	1.53	1.80	1.82	1.84	1.77	1.00	1.20
28	1.50	.50	1.12	.92	1.25	1.53	1.88	1.87	1.84	1.77	1.10	1.20
29	1.40		1.20	1.20	1.25	1.53	1.81	1.88	1.84	1.77	1.20	1.20
30	1.40		1.25	1.20	1.25	1.53	1.80	1.87	1.82	1.77	1.20	1.20
31	1.52		1.25		1.25		1.79	1.87		1.72		

NOTE.—The canal was dry on days when the gage height was not recorded.

Rating table for Central Oregon canal near Bend, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.00	0	0.40	12	0.80	34	1.20	65	1.60	105
0.10	2	0.50	17	0.90	41	1.30	74	1.70	116
0.20	5	0.60	22	1.00	48	1.40	84	1.80	128
0.30	8	0.70	28	1.10	56	1.50	94	1.90	140

NOTE.—The above table is based on 12 discharge measurements made during 1905-6 and is well defined.

Monthly discharge of Central Oregon canal near Bend, Oreg., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
January	96	0	35.2	2,160
February	105	0	26.2	1,460
March	74	0	28.0	1,720
April	70	12	49.6	2,950
May	74	0	58.0	3,570
June	97	70	86.5	5,150
July	138	103	118	7,260
August	138	124	131	8,060
September	138	130	134	7,970
October	133	118	128	7,870
November	114	0	48.5	2,890
December	100	47	73.8	4,540
The year	138	0	76.4	55,600

Note.—Values are rated as good.

Discharge measurements of Pilot Butte canal near Bend, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 18	I. Landes	31.5	33	1.85	37
May 18	do	33	42	2.10	62
June 10	do	33	51	2.30	95
June 18	L. R. Allen	44	58	2.30	99
June 19	J. C. Stevens	34	52	2.30	99

Daily gage height, in feet, of Pilot Butte canal near Bend, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	......	1.95	......	1.85	2.05	2.15	2.44	2.60	2.28	2.46	1.52	1.40
2	......	1.95	1.85	1.50	2.05	2.15	2.44	2.62	2.45	2.45	......	1.36
3	.88	......	1.95	1.50	2.05	2.15	2.44	2.60	2.46	2.43	1.37	1.40
4	1.85	......	1.90	1.62	2.10	2.10	2.44	2.60	2.46	2.44	1.34	1.59
5	.98	......	1.85	1.50	2.15	2.30	2.44	2.60	2.46	2.46	1.38	1.79
6	1.95	......	1.85	1.50	2.15	2.30	2.44	2.60	2.46	2.46	1.38	1.60
7	1.95	......	1.85	1.62	2.15	2.30	2.51	2.60	2.46	2.46	1.80	1.75
8	......	1.95	1.82	1.62	2.15	2.30	2.56	2.60	2.46	2.46	2.26	1.90
9	......	1.95	1.73	1.84	2.15	2.30	2.60	2.60	2.46	2.46	......	1.90
10	1.90	1.95	1.82	2.18	2.22	2.30	2.60	2.60	2.46	2.46	......	1.64
11	1.80	1.95	......	2.30	2.35	2.30	2.60	2.60	2.46	2.45	1.10	1.40
12	.95	1.95	......	2.30	2.35	2.30	2.60	2.60	2.46	2.44	1.36	1.40
13	......	1.85	......	2.05	2.40	2.30	2.60	2.60	2.46	2.44	1.14	1.40
14	......	1.85	......	2.05	2.40	2.30	2.60	2.60	2.46	2.46	1.06	1.39
15	......	1.85	......	2.05	2.40	2.30	2.60	2.60	2.46	2.46	1.02	1.42
16	......	1.85	......	2.00	2.40	2.30	2.60	2.60	2.46	2.44	1.48	1.74
17	......	1.85	......	2.45	2.40	2.30	2.60	2.60	2.46	2.46	1.38	1.90
18	......	1.85	......	2.45	2.05	2.30	2.60	2.60	2.46	2.46	1.42	1.90
19	......	1.85	......	1.95	2.05	2.30	2.60	2.60	2.46	2.46	1.42	1.92
20	......	1.85	......	1.95	2.05	2.30	2.59	2.59	2.46	2.46	1.51	1.92
21	......	1.85	......	1.95	2.10	2.30	2.60	2.60	2.46	2.46	1.74	1.92
22	......	1.85	......	1.95	2.15	2.30	2.60	2.60	2.46	2.46	1.59	1.92
23	......	1.85	......	1.78	2.15	2.30	2.59	2.60	2.43	1.73	1.64	1.92
24	......	1.85	1.78	2.05	2.15	2.37	2.60	2.60	2.46	1.62	2.10	1.92
25	......	1.85	1.95	2.05	2.15	2.42	2.60	2.60	2.46	2.29	2.10	1.92
26	1.50	1.90	1.90	2.05	2.15	2.44	2.60	......	2.46	2.30	2.10	1.92
27	1.75	.97	1.95	2.05	2.20	2.44	2.60	2.60	2.46	2.30	1.75	1.92
28	.90	.98	......	2.05	2.20	2.44	2.59	2.58	2.46	2.30	1.40	1.92
29	.95	......	.85	2.05	2.35	2.44	2.60	......	2.46	2.30	1.38	1.92
30	1.80	......	......	2.05	2.40	2.44	2.58	2.18	2.44	2.30	1.40	1.92
31	1.70	......	......	......	1.78	......	2.35	1.91	......	2.30	......	1.66

Note.—The canal was dry on days when the gage height was not recorded.

Rating table for Pilot Butte canal near Bend, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.90	2	1.30	7	1.70	25	2.10	61	2.50	145
1.00	2	1.40	10	1.80	33	2.20	77	2.60	175
1.10	3	1.50	13	1.90	41	2.30	97		
1.20	5	1.60	18	2.00	49	2.40	120		

Note.—The above table is based on discharge measurements made during 1905-6, and is well defined between gage heights 1.7 feet and 2.3 feet.

Monthly discharge of Pilot Butte canal near Bend, Oreg., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
January	45	0	10.0	615
February	45	0	30.0	1,670
March	45	0	16.0	984
April	132	13	50.8	3,020
May	120	31	79.1	4,860
June	130	69	100	5,950
July	175	108	162	9,960
August	181	0	156	9,590
September	135	93	133	7,910
October	135	19	118	7,260
November	77	2	19.3	1,150
December	43	9	29.9	1,840
The year	181	0	75.3	54,800

Note.—Values are rated as fair.

TUMALO CREEK NEAR LAIDLAW, OREG.

This station was established May 15, 1906. It is located about one-half mile above the head-gate of the Columbia Southern Canal, in sec. 2, T. 18 S., R. 10 E.

The channel is straight; neither bank is liable to overflow, and there is one channel at all stages.

Measurements are made from a footlog. The initial point is a notch cut in the left end of the log.

The gage, which is read voluntarily by G. W. Updike, the ditch tender, is a 1 by 4 inch pine board, graduated with brass tacks, driven in the left bank at the water's edge on the upstream side of the footlog. The bench mark is on top of a fir stump 5 feet from the left bank; elevation, 6.67 feet above the datum of the gage.

Discharge measurements of Tumalo Creek near Laidlaw, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 15	I. Landes	39	59	2.19	218
June 9	.....do	37	46	1.85	144
June 16	L. R. Allen	36	61	2.23	236
June 18	Stevens and Landes	37	55	2.08	202

Daily gage height, in feet, of Tumalo Creek near Laidlaw, Oreg., for 1906.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Day.	May.	June.	July.	Aug.	Sept.	Oct.
1	......	1.85	2.50	1.55	1.50	1.50	17	2.20	2.30	1.65	1.50	1.50	1.55
2	......	2.10	2.65	1.55	1.50	1.65	18	2.40	2.35	1.55	1.50	1.50	1.55
3	......	2.25	2.60	1.50	1.50	1.60	19	2.50	2.40	1.65	1.50	1.50	1.52
4	......	2.15	2.70	1.50	1.50	1.60	20	2.00	2.45	1.70	1.50	1.50	1.52
5	......	1.95	2.60	1.50	1.50	1.55	21	1.95	2.25	1.70	1.50	1.50	1.50
6	......	1.90	2.45	1.50	1.50	1.52	22	1.90	2.20	1.65	1.50	1.50	1.50
7	......	1.80	2.45	1.50	1.50	1.52	23	1.92	2.20	1.65	1.50	1.50	1.50
8	......	1.85	2.40	1.55	1.50	1.52	24	2.00	2.18	1.60	1.50	1.50	1.50
9	......	1.85	2.20	1.55	1.50	1.50	25	2.50	2.60	1.60	1.50	1.50	1.55
10	......	1.80	2.15	1.55	1.50	1.65	26	1.95	2.40	1.60	1.50	1.50	2.15
11	......	2.10	2.15	1.55	1.50	1.85	27	1.90	2.10	1.60	1.50	1.50	1.65
12	......	2.15	2.10	1.55	1.50	1.70	28	1.95	1.90	1.60	1.50	1.50	1.60
13	......	2.10	2.10	1.55	1.62	1.70	29	1.85	2.05	1.60	1.50	1.50	1.55
14	......	2.00	1.95	1.55	1.58	1.67	30	1.80	2.20	1.60	1.50	1.50	1.55
15	2.19	2.55	1.85	1.55	1.50	1.80	31	1.80	......	1.60	1.50	......	1.55
16	2.90	2.45	1.75	1.50	1.50	1.65							

Rating table for Tumalo Creek near Laidlaw, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.50	80	1.90	155	2.20	230	2.50	315	2.80	415
1.60	95	2.00	180	2.30	255	2.60	345	2.90	450
1.70	115	2.10	205	2.40	285	2.70	380	3.00	490
1.80	135								

Note.—The above table is applicable only for open-channel conditions. It is based on 4 discharge measurements made during 1906 and is well defined between gage heights 1.7 feet and 2.5 feet.

Monthly discharge of Tumalo Creek near Laidlaw, Oreg., for 1906.

[Drainage area, 90 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
May 15-31	450	135	210	7,080	2.34	1.48
June	345	135	219	13,000	2.44	2.72
July	380	88	182	11,200	2.01	2.32
August	88	80	82.6	5,080	.918	1.06
September	99	80	81.0	4,820	.900	1.00
October	218	80	98.5	6,060	1.09	1.26
The period	....	....	....	47,200	....	....

Note.—To give the natural flow at this station, the discharge of Wymer canal should be added. Values are rated as good.

TUMALO CREEK NEAR BEND, OREG.

This station was established October 6, 1906, to take the place of the station on Tumalo Creek near Laidlaw during the winter months when no gage reader is available at the latter place. It is located at the highway bridge on the Bend-Sisters road, about 5 miles from Bend, Oreg.

The channel is straight for 175 feet above and 300 feet below the station. The right bank is high; the left, low. There is a single channel.

The gage, which is read by W. P. Downing, is a pine board attached to the river face of the abutment at the southeast corner of the bridge.

Discharge measurements of Tumalo Creek near Bend, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
January 13	Ivan Landes	24	31	1.23	53
April 19	do	26	35	1.52	80
October 6	C. L. Swain			.40	[a] 8

[a] Estimated.

Daily gage height, in feet, of Tumalo Creek near Bend, Oreg., for 1906.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1		1.4	1.6	12	0.80	1.8	1.45	23	0.35	1.4	1.65
2		1.35	1.6	13	.52	2.9	1.5	24	.65	1.5	1.65
3		1.4	1.5	14	.60	3.8	1.5	25	.75	1.55	1.6
4		1.4	1.4	15	.50	2.2	1.5	26	2.00	1.6	1.6
5		1.4	1.45	16	.78	1.9	1.45	27	.95	1.7	1.5
6	0.40	1.45	1.4	17	.32	1.75	1.4	28	.80	1.75	1.5
7	.40	2.2	1.3	18	.32	1.8	1.4	29	.75	2.0	1.5
8	.42	2.45	1.3	19	.31	2.1	1.35	30	.75	1.9	1.45
9	.40	1.5	1.35	20	.30	1.5	1.35	31	.80		1.6
10	.40	3.1	1.4	21	.32	1.5	1.5				
11	.38	1.85	1.4	22	.35	1.4	1.6				

WYMER CANAL NEAR LAIDLAW, OREG.

Wymer canal takes water from Tumalo Creek just above the gaging station on the latter. A gaging station was established on the canal June 16, 1906, in order to determine the total water supply of the creek. It is located just below the headgates.

The bed and banks are of loam and gravel.

Measurements are made from two logs. The gage is a vertical staff and is read by G. W. Updike. The bench mark is on a bench on a fir tree, about 16 inches in diameter, 25 feet below the headgate, and 3 feet from the right bank; elevation, 4.12 feet above the datum of the gage.

Discharge measurements of Wymer canal near Laidlaw, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
May 15	I. Landes	5.5	9		12
June 9	do	4	3.2		8.5
June 16	L. R. Allen	16	22	1.90	41
June 18	Stevens and Landes	15.5	20	1.85	43

Daily gage height, in feet, of Wymer canal near Laidlaw, Oreg., for 1906.

Day.	June.	July.	Aug.	Sept.	Oct.	Day.	June.	July.	Aug.	Sept.	Oct.
1		2.05	1.00	0.88	1.00	17	1.95	1.45	0.88	0.88	1.10
2		2.10	1.00	.88	1.30	18	1.95	1.45	.88	.88	1.10
3		2.05	.95	.88	1.20	19	2.00	1.45	.88	.88	1.10
4		2.15	.95	.88	1.10	20	2.00	1.50	.88	.88	1.10
5		2.05	.95	.88	1.10	21	1.95	1.45	.88	.88	1.05
6		2.05	.95	.88	1.06	22	1.90	1.40	.88	.88	1.05
7		2.05	.95	.88	1.06	23	1.90	1.40	.88	.88	1.10
8		2.00	.95	.88	1.04	24	1.90	1.15	.88	.88	1.15
9		1.95	.95	.88	1.02	25	2.10	1.05	.88	.88	1.20
10		1.90	.95	.88	....	26	2.05	1.05	.88	.88	2.20
11		1.90	.95	.88	....	27	1.95	1.05	.88	.88	1.25
12		1.90	.95	1.28	....	28	1.85	1.05	.88	.88	1.20
13		1.90	.95	1.08	....	29	1.90	1.05	.88	.88	1.20
14		1.75	.95	.95	....	30	1.95	1.05	.88	.88	1.15
15		1.65	.88	.88	....	31	....	1.05	.88	....	1.15
16	1.98	1.55	.88	.88	1.62						

NOTE.—Water turned out October 10 to 15.

COLUMBIA SOUTHERN CANAL NEAR LAIDLAW, OREG.

Columbia Southern canal, which is operated by the Columbia Southern Irrigation Company under provisions of the Carey Act, takes water from Tumalo Creek, 15 miles above its mouth. Measurements are made in the flume 1,000 feet below the head-gate. The gage is set with its zero at the bottom of the flume. It is read by G. W. Updike.

Discharge measurements of Columbia Southern canal near Laidlaw, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 19[a]	I. Landes	20	14	....	35
May 15	do	19.7	31.5	1.60	52
June 9	do	19.7	35	1.78	72
June 16	L. R. Allen	19.6	22	1.15	22
June 16	do	19.6	31	1.62	57
June 18	Stevens and Landes	19.7	33	1.65	63

[a] Measured 9 miles below the head of the canal.

Daily gage height, in feet, of Columbia Southern canal near Laidlaw, Oreg., for 1906.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Day.	May.	June.	July.	Aug.	Sept.	Oct.
1		1.70	1.87	1.75	1.68	1.70	17	1.70	1.65	2.00	1.70	1.68	1.65
2		1.75	1.87	1.75	1.68	1.70	18	1.75	1.65	1.95	1.70	1.68	1.65
3		1.75	1.95	1.75	1.68	1.65	19	1.75	1.65	1.95	1.70	1.68	1.65
4		1.75	1.95	1.75	1.68	1.65	20	1.75	1.65	1.95	1.70	1.68	1.65
5		1.75	1.95	1.75	1.68	1.65	21	1.75	1.70	1.90	1.70	1.68	1.60
6		1.70	2.05	1.75	1.68	1.70	22	1.75	1.70	1.90	1.70	1.68	1.60
7		1.70	2.05	1.75	1.68	1.70	23	1.75	1.70	1.90	1.70	1.68	1.60
8		1.70	2.05	1.75	1.68	1.70	24	1.75	1.70	1.80	1.70	1.68	1.65
9		1.70	2.05	1.75	1.68	1.70	25	1.75	1.80	1.80	1.70	1.70	1.65
10		1.70	2.10	1.75	1.68	1.72	26	1.75	1.85	1.80	1.70	1.70	1.60
11		1.70	2.10	1.75	1.68	1.72	27	1.75	1.80	1.80	1.70	1.70	1.70
12		1.70	2.10	1.75	1.68	1.70	28	1.75	1.80	1.80	1.70	1.70	1.65
13		1.70	2.10	1.75	1.68	1.70	29	1.70	1.87	1.80	1.70	1.70	1.65
14		1.70	2.10	1.75	1.68	1.70	30	1.70	1.87	1.80	1.70	1.70	1.65
15	1.70	1.65	2.00	1.70	1.68	1.70	31	1.70	......	1.80	1.70	......	1.65
16	1.70	1.65	1.88	1.70	1.68	1.70							

Rating table for Columbia Southern canal near Laidlaw, Oreg., for 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.60	55	1.80	74	1.90	86	2.00	99	2.10	114
1.70	64								

NOTE.—The above table is based on 5 discharge measurements made during 1906 and is fairly well defined.

Monthly discharge of Columbia Southern canal near Laidlaw, Oreg., for 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
May 15-31	69	64	67.2	2,260
June	82	60	66.6	3,960
July	114	74	91.7	5,640
August	69	64	66.3	4,080
September	64	62	62.4	3,710
October	66	55	61.3	3,770
The period				23,400

NOTE.—Values are rated as good.

SQUAW CREEK NEAR SISTERS, OREG.

The station was established June 15, 1906. It is located 4 miles south of Sisters and above all present diversions. McAllister ditch, under construction, has its intake 200 feet above the station.

The channel is straight for 200 feet above and 100 feet below the station. The right bank is high and rocky; the left is low and liable to overflow at extreme high water. The bed of the stream is of firm gravel and is permanent. Changes in a dam 250 feet below will change the rating.

Measurements are made from a foot log.

Gage heights are furnished jointly by the Squaw Creek Irrigation Company and citizens of Sisters. The gage is vertical, and nailed to an alder tree on the right bank, about 3 feet above the foot log. The bench mark is the highest point of the sawed part of a pine stump 30 feet to the left and 10 feet upstream from the point of measurement; elevation, 10.27 feet above the datum of the gage.

Discharge measurements of Squaw Creek near Sisters, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq.-ft.*	*Feet.*	*Sec.-ft.*
April 17	I. Landes	31	48	3.65	106
June 8	L. R. Allen	31	46	3.53	105
June 8	I. Landes	31	49	3.60	114
June 15	J. H. Lewis and L. R. Allen	32	65	4.09	205
September 22	C. W. Allen	31	38	3.55	110

Daily gage height, in feet, of Squaw Creek near Sisters, Oreg., for 1906.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.3	3.75	3.6	3.6	3.1	3.0	17	4.1	3.65	3.25	3.35	2.1	1.7
2	4.2	3.7	3.6	3.65	3.1	1.8	18	4.0	3.65	3.35	3.3	2.0	1.65
3	4.4	3.72	3.5	3.65	3.1	1.6	19	2.25	3.6	3.4	3.3	1.95	1.6
4	4.95	3.7	3.55	3.65	3.1	1.6	20	4.05	3.6	3.45	3.3	1.9	2.3
5	4.6	3.8	3.55	3.3	3.1	1.6	21	4.1	3.5	3.45	3.3	1.8	2.05
6	4.6	4.0	3.75	3.35	3.15	1.6	22	4.2	3.5	3.55	3.3	1.8	2.0
7	4.55	4.0	3.8	3.3	5.25	3.0	23	4.2	3.55	3.4	3.35	1.8	1.9
8	4.5	3.85	4.1	3.35	4.1	1.7	24	3.8	3.55	3.35	3.35	1.8	1.95
9	4.3	3.8	3.6	3.3	3.05	1.75	25	3.85	3.55	3.35	3.35	1.7	2.1
10	4.5	4.0	3.5	3.45	5.7	1.7	26	3.75	3.55	3.3	4.0	1.7	2.0
11	4.55	3.9	3.45	3.4	3.4	1.7	27	4.0	3.6	3.3	3.55	1.7	1.9
12	4.9	4.0	3.45	3.35	3.2	1.75	28	4.2	3.6	3.3	3.35	3.5	1.9
13	4.52	3.95	3.4	3.3	4.2	2.9	29	3.95	3.5	3.4	3.3	3.0	1.8
14	4.4	3.8	3.3	3.3	4.5	1.7	30	3.9	3.6	3.4	3.2	2.05	1.8
15	4.35	3.9	3.3	3.3	3.0	1.7	31	3.85	3.5	......	3.2	......	1.75
16	4.1	3.75	3.25	3.3	2.4	1.75							

Note.—Conditions were changed early in November by washing out of dam below; this was replaced November 28, and washed out again December 3. Ice jam December 1 and 13.

Rating table for Squaw Creek near Sisters, Oreg., from July 1 to October 31, 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
3.20	67	3.60	113	4.00	185	4.40	282	4.80	405
3.30	77	3.70	128	4.10	207	4.50	310	4.90	440
3.40	88	3.80	145	4.20	231	4.60	340	5.00	475
3.50	100	3.90	164	4.30	256	4.70	372		

Note.—The above table is applicable only for open-channel conditions. It is based on 5 discharge measurements made during 1906 and it is not well defined.

Monthly discharge of Squaw Creek near Sisters, Oreg., for 1906.

[Drainage area, 90 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
July	458	136	251	15,400	2.79	3.22
August	185	100	133	8,180	1.48	1.71
September	207	72	97.9	5,830	1.09	1.22
October	185	67	88.3	5,400	.981	1.13
The period				34,800		

Note.—Values, July to October, are rated as fair.

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made in Deschutes River drainage basin in 1906:

Miscellaneous measurements in Deschutes River drainage basin, Oregon, in 1906.

Date.	Stream.	Locality.	Width.	Area of section.	Gage height.	Discharge.
			Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
January 9	Crooked River	Forest	50	78	[a]27.43	75
April 16	do	do	135	967	[a]18.71	3,940
May 16	do	do	84	189	[a]25.44	326
June 17	do	do	100	395	[a]23.94	773
October 14	do	do	22	65	[a]24.62	84
April 18[b]	Deschutes Irrigation and Power Company's flume.	Near Bend	14.9	15		83
January 10	Deschutes River	Sec. 36, T. 14 S. R. 12 E.	145	481		1,350
October 13[c]	do	do	138	458		1,230
September 2[d]	do	Moro	260	1,120	1.35	5,040
October 17[d]	do	do	260	1,130	1.40	5,520
October 18	do	Warm Springs Ferry	170	1,690	[e]5.40	4,780
June 8	McAllister ditch	Sisters	7	5		6.9
June 15	do	do	7	5.2		6.6
October 17	Metolius River	Near mouth				[f]2,800
January 6	Ochoco Creek	Prineville	9	4.4	[g]5.88	4.6
April 16	do	do	71	97	[g]4.55	266
May 17	do	do	14	10	[g]5.76	35
June 7	do	do	44	68	[g]4.87	148
June 13	Pole Creek	Sisters	8	4.2		6.2
October 15	Shitike	Warm Springs Agency	26	29	([h])	61
June 10	Swalley canal	Bend, intake flume	7	6		13
June 20	do	Bend, below intake flume	13	10		12
June 20	do	Bend, 5 miles below head	8	5		6.5
October 19	Warm Springs	Warm Springs Agency	92	433	([h])	260
October 20	White River	Tygh Valley	56	56	([h])	165

[a] Below nail in top of floor sill on downstream side of east end of bridge.

[b] Just below headgate; contains discharge of Pilot Butte and Central Oregon canals.

[c] At Tetherow bridge; water surface 4.35 feet below cross cut in northeast corner of bridge on top of abutment.

[d] At Free Bridge gaging station, discontinued December 31, 1899; see Water-Supply Paper No. 38, p. 377, 378.

[e] Below point on alder stump on west bank.

[f] Estimated.

[g] Below reference point on bridge.

[h] Low water.

HOOD RIVER DRAINAGE BASIN.

HOOD RIVER AT WINANS, OREG.

Hood River has its source in the glaciers on the northern slope of Mount Hood, flows north, and unites with Columbia River at the town of Hood River. Its drainage area is wholly mountainous and timbered except where the timber has been removed. A large percentage of its forested area has been burned. The waters of this stream and its tributaries are used for irrigation and power development. The table-lands bordering the river have been cleared of timber and are irrigated by high-line canals. The agricultural products of the district are fruit and berries.

This station was established November 17, 1905. It is located 300 feet below the junction of the main forks of the river at Winans, 10½ miles above Hood River post-office, Oreg. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 219, where are given also references to publications that contain data for previous years.

Discharge measurements of Hood River at Winans, Oreg., in 1905–6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
1905.					
November 17	L. R. Allen	90	147	0.57	493
December 23	do	90	180	1.03	767
1906.					
March 9	P. A. Cupper	99	298	1.90	1,360
May 22 [a]	L. R. Allen	93	188	1.31	702
July 8	do	97	259	1.52	1,160
August 29	do	91	191	.77	571
October 20	J. C. Stevens	95	224	1.17	899
December 15	H. McGlashan	94	253	1.20	864

[a] Not reliable, as débris was lodged against gage.

Daily gage height, in feet, of Hood River at Winans, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.9	1.6	1.8	1.9	2.0	1.3	1.5	1.0	0.7	0.7	1.3	1.1
2	1.0	1.6	1.7	1.8	2.0	1.3	1.5	1.0	.7	.7	1.0	1.2
3	1.0	1.5	1.6	1.7	1.9	1.4	1.6	1.0	.7	.7	.9	1.3
4	1.0	1.5	1.6	1.6	1.9	1.4	1.6	1.0	.7	.7	.9	1.3
5	1.1	1.4	1.5	1.9	1.9	1.4	1.7	1.0	.7	.7	.9	1.4
6	1.2	1.4	1.6	2.0	1.9	1.5	1.7	1.0	.7	.7	.8	1.4
7	1.3	1.3	1.7	2.4	1.9	1.5	1.7	1.0	.7	.7	.8	1.5
8	1.3	1.2	1.9	2.4	1.8	1.6	1.6	1.0	.7	.7	.8	1.5
9	1.4	1.1	1.9	2.2	1.8	1.6	1.5	1.0	.7	.7	.8	1.5
10	1.5	1.1	1.8	2.1	1.8	1.6	1.4	1.0	.7	.7	.9	1.4
11	1.1	1.0	1.6	2.0	1.7	1.6	1.3	1.0	.7	2.0	2.5	1.4
12	1.1	1.0	1.6	1.9	1.7	1.6	1.3	1.0	.7	2.2	4.5	1.3
13	1.1	1.0	1.6	1.9	1.7	1.7	1.3	1.0	.7	2.0	6.4	1.2
14	1.0	1.0	1.6	1.8	1.7	1.8	1.3	1.0	1.2	2.0	6.5	1.2
15	1.0	1.0	1.5	1.8	1.7	1.8	1.3	1.0	1.3	1.9	6.4	1.2
16	1.1	1.0	1.5	1.8	1.6	2.0	1.3	0.9	1.0	1.8	3.7	1.2
17	1.2	1.3	1.5	1.9	1.6	1.9	1.3	.9	.7	1.7	3.4	1.3
18	1.3	3.0	1.6	1.9	1.5	1.7	1.3	.9	.6	1.5	2.7	1.4
19	1.0	3.0	1.6	2.0	1.5	1.7	1.3	.8	.7	1.4	2.4	1.6
20	.9	3.0	1.5	2.1	1.5	1.7	1.3	.8	.7	1.4	2.2	6.6
21	.9	2.9	1.5	2.2	1.5	1.6	1.3	.8	.7	1.4	2.0	4.6
22	1.2	2.8	1.5	2.2	1.4	1.6	1.2	.7	.7	1.4	2.0	3.6
23	1.4	2.4	1.5	2.1	1.4	1.6	1.2	.7	.7	2.0	1.8	3.6
24	2.9	2.3	1.5	2.0	1.4	1.6	1.1	.7	.7	2.0	1.7	3.4
25	2.0	2.2	1.5	2.0	1.5	1.6	1.1	.7	.7	1.9	1.5	3.3
26	1.8	2.2	1.5	2.0	1.5	1.6	1.0	.7	.7	1.8	1.5	3.0
27	1.8	2.0	1.5	2.0	1.5	1.6	.9	.7	.7	1.8	1.4	2.4
28	1.6	1.9	1.5	2.0	1.5	1.6	.9	.7	.7	1.7	1.4	2.2
29	1.7	......	1.6	2.0	1.4	1.6	1.0	.7	.7	1.6	1.2	2.2
30	1.7	......	2.0	2.0	1.4	1.6	1.0	.7	.7	1.5	1.2	2.2
31	1.7	......	2.5	......	1.4	......	1.0	.7	......	1.4	......	2.2

NOTE.—From March to June there was more or less backwater, caused by débris. The flow is influenced by logging dams on the east fork, about 2 miles above the station. These gage heights represent only approximately the daily means.

Rating table for Hood River at Winans, Oreg., for 1905–6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.50	430	1.10	835	1.70	1,325	2.30	1,875	2.90	2,460
0.60	490	1.20	910	1.80	1,415	2.40	1,970	3.00	2,560
0.70	555	1.30	990	1.90	1,505	2.50	2,065	4.00	3,560
0.80	620	1.40	1,070	2.00	1,595	2.60	2,160	5.00	4,660
0.90	690	1.50	1,155	2.10	1,685	2.70	2,260	6.00	5,860
1.00	760	1.60	1,240	2.20	1,780	2.80	2,360		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 6 discharge measurements made during 1905-6 and is well defined between gage heights 0.5 foot and 1.5 feet. Above gage height 2.0 feet it becomes uncertain, and for the highest stages is only approximate.

Monthly discharge of Hood River at Winans, Oreg., for 1905–6.

[Drainage area, 370 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.						
November 19–30	1,160	555	709	16,900	1.92	.857
December	1,420	555	804	49,400	2.17	2.50
The period				66,300		
1906.						
January	2,460	690	1,030	63,300	2.78	3.20
February	2,560	760	1,400	77,800	3.78	3.94
March	2,060	1,150	1,280	78,700	3.46	3.99
April	1,970	1,240	1,590	94,600	4.30	4.80
May	1,600	1,070	1,280	78,700	3.46	3.99
June	1,600	990	1,240	73,800	3.35	3.74
July	1,320	690	1,000	61,500	2.70	3.11
August	760	555	674	41,400	1.82	2.10
September	990	490	586	34,900	1.58	1.76
October	1,780	555	1,100	67,600	2.97	3.42
November	6,460	620	1,890	112,000	5.11	5.70
December	6,580	835	1,740	107,000	4.70	5.42
The year	6,580	490	1,230	891,000	3.33	45.17

NOTE.—Values are rated as follows: March to June, 1906, approximate; remainder of 1905 and 1906, good. Débris caused backwater to a greater or less extent.

WILLAMETTE RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Willamette River is formed by the junction of Middle and Coast forks near Eugene, Oreg., from which point it flows in a general northerly direction to its point of junction with the Columbia, about 10 miles north of Portland. Coast Fork rises in the eastern slope of the Coast Range and Middle Fork on the western slope of the Cascade Mountains. The tributaries of this stream flow both east and west, draining heavily timbered mountain areas. Many of them afford extensive power possibilities. At present the development in this line is in the primitive state. The natural resources of the Willamette Valley would make it an unrivaled manufacturing center. There is unlimited water power, an abundance of raw material, and adequate transportation facilities. The principal tributaries of this stream are the McKenzie, Santiam, Luckiamute, Molalla, Yamhill, and Clackamas rivers.

WILLAMETTE RIVER AT ALBANY, OREG.

This station was established July 21, 1905. It is located at the Corvallis and Eastern Railroad bridge at Albany, Oreg., just above the mouth of Calipooia Creek and 7 miles above the mouth of Santiam River. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 223.

Discharge measurements of Willamette River at Albany, Oreg., in 1905–1907.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
1905.					
July 20	L. R. Allen		3,720	3.29	3,430
1906.					
January 6	L. R. Allen	438	5,160	6.56	13,400
February 8	do	439	4,860	5.84	11,700
March 28	do	438	4,900	6.12	13,300
May 9	do	433	4,380	5.10	9,380
July 25	do	428	3,610	2.92	4,360
September 5	I. E. Oakes	425	3,580	2.20	2,960
1907.					
February 5	I. E. Oakes	2,960	38,500	27.55	146,000

Daily gage height, in feet, of Willamette River at Albany, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	9.3	7.5	12.7	7.9	6.05	7.8	4.45	2.8	2.4	2.35	3.1	5.05
2	8.8	7.45	10.5	8.3	5.85	6.9	4.25	2.75	2.35	2.3	2.95	4.8
3	7.4	7.15	9.4	7.55	5.75	6.5	4.2	2.7	2.3	2.3	2.9	4.65
4	6.8	7.05	8.7	6.98	5.55	6.3	4.1	2.7	2.3	2.35	2.95	4.4
5	6.75	6.75	8.25	6.68	5.5	6.8	3.95	2.7	2.2	2.4	3.15	4.5
6	6.55	6.55	7.75	6.48	5.4	6.55	3.8	2.6	2.2	2.4	3.35	4.5
7	6.5	6.2	7.6	6.28	5.25	6.7	3.75	2.6	2.2	2.4	3.9	4.7
8	6.4	5.8	7.5	6.18	5.05	7.1	3.7	2.6	2.2	2.4	6.9	5.6
9	6.75	5.75	7.5	6.08	5.1	6.9	3.7	2.6	2.2	2.3	9.3	6.6
10	8.3	5.6	7.45	6.3	5.0	7.3	3.55	2.6	2.2	2.3	7.6	7.1
11	8.1	5.5	7.4	6.05	5.1	7.2	3.3	2.6	2.1	2.35	7.2	7.5
12	8.3	5.35	7.25	5.8	5.1	6.9	3.3	2.6	2.15	2.4	7.1	7.55
13	9.0	5.2	6.7	5.55	5.0	6.65	3.3	2.55	2.2	2.45	6.9	6.8
14	10.25	5.1	6.4	5.35	4.9	6.5	3.25	2.5	2.3	2.65	8.4	6.45
15	10.2	4.85	6.15	5.25	5.0	6.3	3.2	2.5	2.3	2.7	10.95	6.2
16	10.3	5.05	5.75	5.25	5.7	6.6	3.2	2.5	2.5	2.9	12.35	6.65
17	13.0	5.15	5.55	5.3	5.75	7.4	3.1	2.5	2.8	3.45	13.1	8.15
18	15.0	5.75	5.38	5.2	5.4	7.05	3.1	2.5	2.9	4.6	12.9	7.35
19	13.0	7.05	5.32	5.08	5.2	6.6	3.1	2.5	2.75	4.65	13.05	7.3
20	11.8	9.85	5.42	4.92	5.1	6.5	3.1	2.5	2.65	4.3	10.7	8.8
21	9.8	11.6	5.72	5.42	5.1	5.8	3.1	2.6	2.6	4.05	9.35	11.4
22	8.85	13.25	6.2	5.25	5.35	5.55	3.0	2.6	2.4	3.7	9.25	10.95
23	8.15	12.55	6.32	5.4	5.8	5.3	3.0	2.6	2.4	3.4	8.9	9.8
24	9.6	12.85	6.25	5.22	5.9	5.1	3.0	2.65	2.5	3.25	8.0	9.85
25	10.6	14.8	6.18	5.5	5.7	4.9	2.9	2.8	2.5	3.2	7.1	9.45
26	10.25	15.1	6.08	5.68	5.6	4.6	2.9	2.95	2.6	3.1	6.55	10.65
27	9.4	13.9	6.1	5.95	5.6	4.5	2.85	2.75	2.55	2.9	6.2	11.45
28	8.55	13.5	6.22	5.9	5.55	4.5	2.8	2.6	2.5	3.3	5.85	10.5
29	8.1	....	6.42	6.4	7.2	4.55	2.8	2.5	2.5	3.25	5.55	9.4
30	7.65	....	5.8	6.25	9.95	4.55	2.8	2.5	2.4	3.15	5.25	8.5
31	7.5	....	6.1	....	8.9	....	2.8	2.4	....	3.1	....	8.4

Rating tables for Willamette River at Albany, Oreg.

1905.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.00	1,755	2.90	2,835	3.80	4,320	4.70	6,260	6.20	10,300
2.10	1,855	3.00	2,980	3.90	4,510	4.80	6,500	6.40	10,910
2.20	1,960	3.10	3,130	4.00	4,710	4.90	6,750	6.60	11,530
2.30	2,070	3.20	3,385	4.10	4,910	5.00	7,000	6.80	12,160
2.40	2,185	3.30	3,445	4.20	5,120	5.20	7,500	7.00	12,800
2.50	2,305	3.40	3,610	4.30	5,340	5.40	8,020	8.00	16,000
2.60	2,430	3.50	3,780	4.40	5,560	5.60	8,560	9.00	19,400
2.70	2,560	3.60	3,955	4.50	5,790	5.80	9,120		
2.80	2,695	3.70	4,135	4.60	6,020	6.00	9,700		

[a] This table is applicable only for open-channel conditions. It is based on one discharge measurement made during 1905 and the form of the 1906 curve and is not well defined.

Rating tables for Willamette River at Albany, Oreg.—Continued.

1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.00	2,670	3.10	4,730	4.20	7,240	5.60	11,010	7.80	18,060
2.10	2,810	3.20	4,950	4.30	7,480	5.80	11,600	8.00	18,800
2.20	2,960	3.30	5,170	4.40	7,730	6.00	12,200	9.00	22,700
2.30	3,120	3.40	5,390	4.50	7,980	6.20	12,800	10.00	27,000
2.40	3,290	3.50	5,610	4.60	8,230	6.40	13,410	11.00	31,600
2.50	3,470	3.60	5,840	4.70	8,490	6.60	14,030	12.00	36,400
2.60	3,660	3.70	6,070	4.80	8,760	6.80	14,660	13.00	41,300
2.70	3,860	3.80	6,300	4.90	9,030	7.00	15,300	14.00	46,700
2.80	4,070	3.90	6,530	5.00	9,300	7.20	15,960	15.00	52,200
2.90	4,290	4.00	6,760	5.20	9,860	7.40	16,640		
3.00	4,510	4.10	7,000	5.40	10,430	7.60	17,340		

[a] This table is applicable only for open-channel conditions. It is based on 6 discharge measurements made during 1906 and 1 during 1907 and is well defined between gage heights 2.2 feet and 6.5 feet.

Monthly discharge of Willamette River at Albany, Oreg., for 1905–6.

[Drainage area, 4,860 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.						
September	2,560	1,800	2,020	120,000	0.416	0.46
October[a]	6,750	2,700	3,750	231,000	.772	.89
November[a]	5,900	2,430	3,450	205,000	.710	.79
December	18,700	4,910	9,650	593,000	1.99	2.29
The period				1,150,000		
1906.						
January	52,200	13,400	23,600	1,450,000	4.86	5.60
February	52,800	8,900	21,900	1,220,000	4.51	4.70
March	39,800	10,200	15,700	965,000	3.23	3.72
April	19,900	9,080	12,200	726,000	2.51	2.80
May	26,800	9,030	11,500	707,000	2.37	2.73
June	18,100	7,980	12,900	768,000	2.65	2.96
July	7,860	4,070	5,260	323,000	1.08	1.24
August	4,400	3,290	3,680	226,000	.757	.87
September	4,290	2,810	3,320	198,000	.683	.76
October	8,360	3,120	4,530	279,000	.932	1.07
November	41,800	4,290	18,200	1,080,000	3.74	4.17
December	33,800	7,730	18,200	1,120,000	3.74	4.31
The year	52,800	2,810	12,600	9,060,000	2.59	34.93

[a] Gage heights published in Water-Supply Paper No. 178 as 2.11 feet should be 2.9 feet, 3.11 should be 3.9, and 2.1 should be 2.8.

NOTE.—Values are rated as follows: September, 1905, to February, 1906, fair; March to December, 1906, good.

MIDDLE FORK OF WILLAMETTE RIVER AT JASPER, OREG.

This station was established September 16, 1905. It is located at Jasper Ferry, Jasper post-office, Oreg., 2 miles above Natron and 3 miles below the mouth of Fall Creek. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 220.

Discharge measurements of Middle Fork of Willamette River at Jasper, Oreg., in 1905–1907.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1905.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
September 16	L. R. Allen	322	652	1.25	758
December 29	do	354	1,370	3.27	3,920
1906.					
February 3	L. R. Allen	368	1,590	3.87	5,530
March 23	do	357	1,400	[a] 3.38	3,890
May 5	do	356	1,420	[a] 3.52	5,280
August 17	do	325	726	1.48	953
September 17	I. E. Oakes	327	807	1.70	1,130
1907.					
January 30	do	396	2,730	7.10	21,100

[a] Affected by log jam.

Daily gage height, in feet, of Middle Fork of Willamette River at Jasper, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.6	3.8	4.4	4.6	3.6	4.0	2.6	1.7	1.4	1.4	1.6	2.5
2	3.1	3.8	4.1	4.2	3.5	3.9	2.6	1.7	1.4	1.4	1.6	2.5
3	3.1	3.9	4.0	4.1	3.5	3.8	2.5	1.6	1.4	1.5	1.6	2.4
4	3.1	3.7	3.9	3.8	3.4	4.1	2.5	1.6	1.4	1.9	1.6	2.3
5	3.0	3.6	3.7	3.7	3.4	4.0	2.5	1.7	1.4	1.5	2.0	2.4
6	3.2	3.6	3.7	3.6	3.3	4.1	2.4	1.6	1.4	1.5	2.0	2.7
7	3.2	3.4	3.8	3.6	3.3	4.4	2.3	2.0	1.4	1.5	3.3	2.7
8	3.3	3.3	3.9	3.5	3.2	4.3	2.2	1.8	1.4	1.4	4.6	3.6
9	4.6	3.2	4.0	3.7	3.2	4.4	2.1	2.0	1.5	1.4	3.7	3.6
10	4.3	3.1	4.1	3.6	3.4	4.5	2.1	2.2	1.5	1.4	3.2	3.6
11	4.0	3.0	3.9	3.4	3.5	4.2	2.0	2.2	1.4	1.4	3.7	3.7
12	4.2	2.9	3.7	3.2	3.3	4.1	2.0	2.3	1.5	1.5	3.2	3.5
13	4.5	2.8	3.5	3.2	3.2	4.0	2.0	2.0	2.2	1.7	4.1	3.2
14	4.2	2.8	3.3	3.1	3.1	3.8	1.9	2.2	1.9	1.6	4.9	3.1
15	4.1	2.8	3.2	3.0	3.6	3.7	1.9	1.5	2.4	1.6	5.6	3.0
16	6.3	2.9	3.0	3.0	3.4	4.4	1.9	1.5	2.0	2.2	6.1	4.4
17	5.9	3.1	2.9	3.1	3.2	4.2	2.0	1.5	1.7	2.9	5.9	4.0
18	4.9	3.4	2.8	3.0	3.0	3.9	1.8	1.5	1.6	2.7	6.0	3.7
19	4.2	5.1	2.8	2.9	2.9	3.6	1.8	1.5	1.5	2.6	4.8	4.4
20	4.0	5.05	2.8	2.9	2.9	3.5	1.8	1.5	1.5	2.2	4.2	5.7
21	3.5	5.4	3.0	2.9	3.2	3.3	1.7	1.4	1.5	2.1	4.5	5.3
22	3.4	5.1	3.2	3.0	3.4	3.7	1.6	1.4	1.4	1.9	4.3	4.6
23	4.0	4.8	3.2	3.1	3.6	3.1	1.7	1.4	1.5	1.8	4.0	4.3
24	5.2	5.5	3.3	3.4	3.4	3.1	1.7	1.4	1.5	1.7	3.6	4.2
25	5.0	5.5	3.4	3.4	3.4	2.8	1.7	1.4	1.6	1.7	3.3	4.5
26	4.8	4.9	3.5	3.6	3.3	2.8	1.8	1.4	1.6	1.6	3.2	5.3
27	4.7	5.0	3.4	3.4	3.3	2.8	1.7	1.3	1.5	2.1	3.0	4.8
28	4.2	4.7	3.3	3.8	4.2	2.9	1.7	1.4	1.5	1.9	2.8	4.3
29	4.0	....	3.3	3.7	5.7	2.8	1.6	1.4	1.4	1.7	2.8	4.0
30	3.9	....	3.3	3.6	5.1	2.7	1.6	1.4	1.4	1.7	2.6	4.0
31	3.8	....	4.1	....	4.6	....	1.6	1.4	....	1.6	....	4.0

NOTE.—From June to August the discharge showed considerable daily fluctuation, caused by storage at logging dams. There was also some backwater from log jams during the same period, especially August 7 to 14.

Rating table for Middle Fork of Willamette River at Jasper, Oreg., for 1905–6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.20	730	2.20	1,790	3.20	3,750	4.20	6,690	5.40	11,670
1.30	800	2.30	1,940	3.30	3,990	4.30	7,050	5.60	12,650
1.40	880	2.40	2,110	3.40	4,240	4.40	7,420	5.80	13,680
1.50	960	2.50	2,290	3.50	4,500	4.50	7,800	6.00	14,750
1.60	1,050	2.60	2,480	3.60	4,780	4.60	8,190	6.20	15,860
1.70	1,150	2.70	2,670	3.70	5,070	4.70	8,590	6.40	16,990
1.80	1,260	2.80	2,870	3.80	5,370	4.80	9,000	6.60	18,150
1.90	1,380	2.90	3,080	3.90	5,680	4.90	9,420	6.80	19,320
2.00	1,510	3.00	3,300	4.00	6,000	5.00	9,850	7.00	20,500
2.10	1,650	3.10	3,520	4.10	6,340	5.20	10,740		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 6 discharge measurements made during 1905-1907 and is fairly well defined.

Monthly discharge of Middle Fork of Willamette River at Jasper, Oreg., for 1905–6.

[Drainage area, 1,450 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.						
September 16-30	1,380	730	868	25,800	0.599	0.33
October	3,520	880	1,580	97,200	1.09	1.26
November	3,520	880	1,430	85,100	.986	1.10
December	6,340	1,790	3,360	207,000	2.32	2.68
The period	6,340	1,790	....	415,000	....	....
1906.						
January	16,400	3,300	6,720	413,000	4.63	5.34
February	12,200	2,870	6,290	349,000	4.34	4.52
March	7,420	2,870	4,610	283,000	3.18	3.67
April	8,190	3,080	4,430	264,000	3.06	3.41
May	13,200	3,080	4,760	293,000	3.28	3.78
June	7,800	2,670	5,240	312,000	3.61	4.03
July	2,480	1,050	1,530	94,100	1.06	1.22
August [a]	1,150	800	969	59,600	.668	.77
September	2,110	880	1,040	61,900	.717	.80
October	3,080	880	1,310	80,600	.903	1.04
November	15,300	1,050	5,710	340,000	3.94	4.40
December	13,200	1,940	5,670	349,000	3.91	4.51
The year	16,400	800	4,020	2,900,000	2.77	37.49

[a] August 7 to 14, discharge estimated at 1,000 second-feet.

NOTE.—Values are rated as follows: September, 1905, to February, 1906, and September to December, 1906, excellent; March, April, July, and August, good; May and June, fair.

COAST FORK OF WILLAMETTE RIVER NEAR GOSHEN, OREG.

This station was established August 23, 1905. It is located at the highway bridge 3 miles east of Goshen, Oreg., 9 miles southeast of Eugene, and about 4 miles above the junction of Coast and Middle forks of Willamette River. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 221.

Discharge measurements of Coast Fork of Willamette River near Goshen, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1905.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
August 23	L. R. Allen	80	47	0.30	67.6
November 7	.....do	165	204	.67	182
December 29	.....do	241	677	2.78	1,910
1906.					
February 2	L. R. Allen	242	570	2.38	1,620
March 22	.....do	243	697	2.87	2,260
May 3	.....do	234	402	1.70	917
July 16	.....do	160	226	.82	252
August 17	.....do	145	158	.58	132
September 19	I. E. Oakes	154	168	.65	145
1907.					
January 31	I. E. Oakes	256	1,870	7.75	10,700

Daily gage height, in feet, of Coast Fork of Willamette River near Goshen, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.7	2.5	4.3	4.7	2.0	3.4	1.3	0.6	0.3	0.7	0.8	1.4
2	3.0	2.5	3.7	3.7	1.8	2.9	1.3	.6	.3	.7	.8	1.4
3	2.8	2.0	3.3	3.2	1.7	2.8	1.2	.6	.3	.6	.8	1.5
4	2.8	2.0	3.2	3.0	1.5	3.0	1.2	.6	.3	.5	1.0	1.5
5	3.1	2.0	3.0	2.7	1.5	2.7	1.3	.6	.3	.7	1.5	1.7
6	3.0	1.8	3.0	2.6	1.5	2.6	1.1	.6	.3	.7	1.6	1.8
7	2.7	1.8	2.9	2.5	1.5	2.7	1.1	.5	.3	.5	1.9	2.3
8	2.5	1.7	2.9	2.2	1.4	2.9	1.1	.5	.3	.5	2.0	2.9
9	5.0	1.6	2.8	2.3	1.4	3.5	1.1	.5	.3	.5	2.5	3.0
10	4.0	1.6	2.7	2.2	1.4	3.0	1.0	.5	.3	.6	2.0	3.4
11	3.6	1.6	2.5	2.0	1.4	2.7	1.0	.5	.3	.6	2.0	3.0
12	3.5	1.5	2.3	1.9	1.3	2.5	1.0	.5	.5	.8	2.0	2.7
13	5.4	1.3	2.1	1.7	1.3	2.5	1.0	.5	.5	1.0	2.0	2.3
14	4.5	1.3	2.0	1.7	1.4	2.3	.9	.4	.8	1.0	3.0	2.3
15	4.3	1.7	1.9	1.6	2.2	2.3	.9	.4	1.0	1.0	3.4	2.1
16	5.7	1.4	1.8	1.5	2.5	2.3	.8	.4	1.0	1.2	5.2	4.0
17	7.5	1.6	1.6	1.5	2.2	2.9	.8	.5	.8	1.5	4.3	3.7
18	5.4	2.0	1.7	1.5	2.0	2.6	.8	.5	.8	1.9	5.0	3.0
19	4.5	4.5	1.7	1.4	2.0	2.3	.8	.5	.7	1.8	4.7	3.2
20	3.7	3.7	1.9	1.4	2.0	2.0	.8	.5	.5	1.7	3.0	4.4
21	3.3	6.2	2.7	1.4	1.9	2.0	.8	.5	.5	1.5	3.6	4.0
22	3.0	5.6	2.9	1.5	2.4	1.8	.8	.5	.5	1.4	3.0	3.0
23	3.5	5.2	2.6	1.6	2.9	1.5	.8	.5	.6	1.4	3.0	3.0
24	5.4	7.0	2.5	1.6	2.5	1.6	.8	.5	.7	1.0	2.6	3.4
25	4.4	7.0	2.4	1.7	2.3	1.6	.8	.4	1.0	1.0	2.3	4.0
26	3.7	5.3	2.2	2.0	2.3	1.5	.7	.3	.8	1.0	2.0	5.0
27	3.5	6.0	2.2	1.9	2.1	1.5	.7	.3	.7	1.0	2.0	4.2
28	3.5	5.0	2.1	2.7	2.5	1.5	.7	.3	.6	.9	2.0	3.3
29	2.7	....	2.0	2.7	9.5	1.5	.7	.3	.6	.9	1.7	2.6
30	2.7	....	2.0	2.2	5.7	1.4	.7	.3	....	.9	1.5	2.6
31	2.6	....	3.0	....	4.4	....	.7	.3	....	.8	....	2.3

Rating table for Coast Fork of Willamette River near Goshen, Oreg., for 1905–6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.20	52	1.40	635	2.60	1,880	3.80	3,610	6.00	7,670
0.30	68	1.50	720	2.70	2,005	3.90	3,775	6.20	8,070
0.40	89	1.60	810	2.80	2,135	4.00	3,940	6.40	8,470
0.50	115	1.70	905	2.90	2,270	4.20	4,280	6.60	8,870
0.60	147	1.80	1,005	3.00	2,410	4.40	4,625	6.80	9,270
0.70	186	1.90	1,105	3.10	2,550	4.60	4,980	7.00	9,670
0.80	232	2.00	1,210	3.20	2,695	4.80	5,350	8.00	11,750
0.90	285	2.10	1,315	3.30	2,840	5.00	5,720	9.00	13,850
1.00	345	2.20	1,420	3.40	2,990	5.20	6,100	10.00	16,050
1.10	410	2.30	1,530	3.50	3,140	5.40	6,485		
1.20	480	2.40	1,645	3.60	3,295	5.60	6,875		
1.30	555	2.50	1,760	3.70	3,450	5.80	7,270		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 9 discharge measurements made during 1905–1907 and is well defined between gage heights 0.3 foot and 3.0 feet.

Monthly discharge of Coast Fork of Willamette River near Goshen, Oreg., for 1905-6.

[Drainage area, 690 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft per sq. mile.	Depth in inches.
1905.[a]						
August 23-31	68	58	64.7	1,150	0.094	0.031
September 1-20	58	52	56.5	2,240	.082	.061
October 4-31	1,530	115	492	27,300	.713	.742
November	2,410	68	483	28,700	.701	.782
December	5,720	555	1,870	115,000	2.71	3.12
The period				174,000		
1906.[b]						
January	10,700	1,760	3,820	235,000	5.54	6.39
February	9,670	555	3,080	171,000	4.46	4.64
March	4,450	810	1,790	110,000	2.59	2.99
April	5,160	635	1,460	86,900	2.12	2.36
May	15,000	555	1,870	115,000	2.71	3.12
June	3,140	635	1,620	96,400	2.35	2.62
July	555	186	311	19,100	.451	.520
August	147	68	109	6,700	.158	.182
September	345	68	147	8,750	.213	.238
October	1,100	115	373	22,900	.541	.62
November	6,100	232	1,920	114,000	2.78	3.10
December	5,720	635	2,410	148,000	3.49	4.02
The year	15,000	68	1,580	1,130,000	2.28	30.80

[a] Values for 1905 are rated as follows: August to November, good; December, fair.
[b] Values for 1906 are rated as excellent.

M'KENZIE RIVER NEAR SPRINGFIELD, OREG.

This station was established September 12, 1905, by L. R. Allen. It is located at Hendricks Ferry, 11 miles above Springfield, about 3 miles above the mouth of Camp Creek. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 222.

Discharge measurements of McKenzie River near Springfield, Oreg., in 1905-6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1905.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
September 12	L. R. Allen	395	928	1.30	1,570
November 10	do	398	880	1.12	1,810
December 30	do	404	1,370	2.65	4,900
1906.					
February 5	L. R. Allen	372	1,400	2.66	5,280
March 24	do	342	1,190	2.14	3,690
May 4	do	384	1,400	2.71	5,040
June 7	do	379	1,430	[a]2.77	5,160
July 26	do	327	1,100	[a]1.40	2,250
August 15	do	328	1,110	[a]1.40	1,960
September 18	I. E. Oakes	315	924	1.05	1,860

[a] Affected by log jam.

Daily gage height, in feet, of McKenzie River near Springfield, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.4	3.1	3.3	3.55	2.75	2.85	1.9	1.4	1.4	1.0	1.3	2.1
2	2.2	3.0	3.1	2.85	2.65	2.75	1.85	1.4	1.4	1.15	1.3	2.0
3	2.1	2.9	3.0	2.7	2.65	2.7	1.8	1.4	1.4	1.15	1.3	1.9
4	2.2	2.75	2.85	2.65	2.7	2.7	1.8	1.4	1.4	1.1	1.4	1.95
5	2.3	2.55	2.8	2.5	2.6	2.8	1.75	1.4	1.4	1.1	1.5	2.0
6	2.45	2.5	2.9	2.75	2.6	3.0	1.75	1.4	1.4	1.1	1.55	2.05
7	2.5	2.4	3.0	2.8	2.5	3.25	1.7	1.4	1.4	1.05	1.35	3.1
8	2.5	2.3	3.3	2.9	2.5	3.15	1.7	1.4	1.4	1.05	4.6	2.95
9	3.2	2.2	3.2	3.0	2.5	3.4	1.65	1.4	1.4	1.0	3.2	2.75
10	2.8	2.1	3.15	2.85	2.5	3.2	1.7	1.4	1.4	1.0	3.7	2.7
11	3.0	2.1	2.85	2.7	2.45	3.05	1.8	1.4	1.4	1.0	4.4	2.6
12	3.1	2.05	2.7	2.6	2.35	2.8	1.85	1.4	1.6	1.3	3.0	3.1
13	3.3	2.0	2.6	2.55	2.25	2.7	1.95	1.4	1.8	1.15	5.6	3.2
14	3.05	2.0	2.4	2.55	2.7	3.1	2.05	1.45	2.15	1.25	6.5	3.2
15	2.85	2.1	2.3	2.7	2.6	3.45	2.0	1.4	2.25	1.3	6.5	2.95
16	4.25	2.15	2.2	2.75	2.55	3.4	2.05	1.4	1.8	1.95	6.2	2.9
17	3.7	2.4	2.15	2.8	2.45	3.1	1.5	1.4	1.2	2.6	5.35	2.9
18	3.5	3.0	2.1	2.75	2.4	2.95	1.4	1.4	1.1	2.3	4.3	2.8
19	3.2	3.95	2.0	2.7	2.35	2.8	1.4	1.4	1.05	2.2	4.1	2.75
20	2.95	4.6	2.0	2.35	2.35	2.45	1.45	1.4	1.25	1.9	4.0	4.0
21	2.5	4.2	2.1	2.5	2.55	2.3	1.45	1.4	1.2	1.6	3.9	6.0
22	2.95	4.05	2.1	2.55	2.6	2.2	1.5	1.4	1.15	1.45	3.6	4.9
23	4.9	4.1	2.0	2.85	2.55	2.15	1.45	1.4	1.1	1.4	3.3	4.85
24	4.45	4.3	2.15	3.0	2.5	2.1	1.45	1.4	1.1	1.4	3.2	4.65
25	4.2	4.05	2.24	3.15	2.5	2.05	1.45	1.4	1.1	1.35	2.9	4.4
26	3.6	3.9	2.5	2.9	2.55	2.0	1.45	1.4	1.05	1.7	2.6	4.15
27	3.35	3.6	2.55	2.85	2.45	2.0	1.45	1.4	1.05	2.0	2.55	3.9
28	3.2	3.45	2.5	2.9	3.7	2.05	1.4	1.4	1.05	1.7	2.45	3.65
29	3.0	....	2.5	2.8	3.65	2.0	1.4	1.4	1.0	1.8	2.3	3.45
30	3.15	....	2.8	2.75	3.45	1.95	1.4	1.4	1.0	1.6	2.2	3.2
31	3.3	....	3.5	....	3.0	....	1.4	1.4	....	1.8	....	2.95

Rating table for McKenzie River near Springfield, Oreg., for 1905-6.

Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.00	1,630	1.80	3,000	2.60	4,760	3.40	6,920	4.40	10,090
1.10	1,780	1.90	3,200	2.70	5,010	5.50	7,210	4.60	10,770
1.20	1,930	2.00	3,410	2.80	5,270	3.60	7,510	4.80	11,450
1.30	2,090	2.10	3,620	2.90	5,530	3.70	7,820	5.00	12,150
1.40	2,260	2.20	3,840	3.00	5,800	3.80	8,130	6.00	15,650
1.50	2,440	2.30	4,060	3.10	6,070	3.90	8,450	7.00	19,250
1.60	2,620	2.40	4,290	3.20	6,350	4.00	8,770		
1.70	2,810	2.50	4,520	3.30	6,630	4.20	9,420		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 6 discharge measurements made during 1905-6 and is fairly well defined between gage heights 1 foot and 3 feet.

Monthly discharge of McKenzie River near Springfield, Oreg., for 1905–6.

[Drainage area, 960 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.[a]						
September 12–30	2,810	2,090	2,230	84,000	2.32	1.64
October	5,270	2,090	2,770	170,000	2.89	3.33
November	4,060	1,780	2,260	134,000	2.35	2.62
December	6,920	2,810	4,010	247,000	4.18	4.82
The period	....	....	....	635,000	....	....
1906.[b]						
January	11,800	3,620	6,200	381,000	6.46	7.45
February	10,800	3,410	5,980	332,000	6.23	6.49
March	7,210	3,410	4,850	298,000	5.05	5.82
April	7,360	4,170	5,220	311,000	5.44	6.07
May	7,820	3,950	4,900	301,000	5.10	5.88
June	7,060	3,300	5,040	300,000	5.25	5.86
July	3,510	2,260	2,710	167,000	2.82	3.25
August	2,350	2,260	2,260	139,000	2.35	2.71
September[c]	3,950	1,630	2,200	131,000	2.29	2.56
October	4,760	1,630	2,440	150,000	2.54	2.93
November	17,400	2,090	7,300	434,000	7.60	8.48
December	15,600	3,200	6,650	409,000	6.93	7.99
The period	17,400	1,630	4,650	3,350,000	4.84	65.49

[a] Values for 1905 are rated as follows: November and December, excellent; October, fair; September, approximate.

[b] Values are rated as follows: January to July, good; August to December, fair.

[c] During the morning of September 17, 1906, there was a drop of 0.5 foot in the water due to the removal of a log jam lodged on a bar 200 yards below the gage. The daily discharge September 12 to 17 was applied as if open-channel conditions existed. It is impossible to judge accurately the extent of the backwater effect from this log jam owing to a natural rise from rains about the middle of September, but the monthly mean for this month is believed to be not more than 2 or 3 per cent too high from this cause. Estimates for this station are affected by log drives which cause changes in the channel and modify the flow generally.

NORTH FORK OF SANTIAM RIVER AT MEHAMA, OREG.

This station was established July 11, 1905. It is located just below the highway bridge at Mehama, Oreg., about 1½ miles north of Lyons, the nearest railroad station, which is about 12 miles below the junction of Little North Fork and North Fork. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 224.

Discharge measurements of North Fork of Santiam River at Mehama, Oreg., in 1905–1907.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1905.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
July 11	L. R. Allen	160	756	2.90	1,050
October 18[a]	do	202	1,010	4.44	3,560
November 16	J. H. Lewis	155	756	2.90	973
December 12	L. R. Allen	250	927	4.24	2,880
1906.					
January 4[a]	L. R. Allen	249	926	4.20	2,230
February 7	do	251	1,000	4.51	3,320
March 26	do	250	927	4.20	2,740
May 7	do	250	947	4.28	2,800
May 15[b]	do	253	1,030	4.65	3,060
July 17	do	242	632	3.04	1,080
August 21	do	237	550	2.64	756
September 27	I. E. Oakes	242	585	2.83	906
1907.					
February 6	I. E. Oakes	305	2,710	11.00	29,100

[a] Measurement unreliable. [b] Backwater from log jam.

Daily gage height, in feet, of North Fork of Santiam River at Mehama, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.35	5.8	5.5	5.45	5.0	4.3	3.8	2.8	2.6	2.7	3.3	3.75
2	4.2	5.9	5.3	5.0	4.6	4.1	3.8	2.8	2.55	2.8	3.25	3.7
3	4.1	5.5	5.2	4.7	4.6	4.2	3.7	2.8	2.55	3.55	3.2	3.7
4	4.2	5.2	5.15	4.55	4.6	4.8	3.65	2.75	2.55	3.6	3.45	3.5
5	4.4	5.0	5.0	4.55	4.6	4.5	3.6	2.75	2.55	3.3	3.8	3.75
6	4.5	4.75	5.25	4.8	4.3	5.0	3.5	2.75	2.55	3.1	3.7	4.0
7	4.5	4.6	5.4	5.0	4.3	5.4	3.4	2.75	2.55	2.95	9.65	6.2
8	4.6	4.4	5.6	5.0	4.3	5.1	3.35	2.75	2.55	2.9	10.0	5.5
9	5.1	4.25	5.5	5.3	4.5	5.1	3.3	2.75	2.65	2.8	6.9	5.2
10	4.85	4.15	5.65	5.0	4.6	5.1	3.25	2.7	2.65	2.8	8.5	4.8
11	5.5	4.05	5.2	5.0	5.0	4.7	3.25	2.7	2.6	2.8	6.5	4.85
12	5.0	4.0	4.9	5.0	4.45	4.8	3.2	2.7	2.7	3.25	6.75	4.6
13	5.3	3.9	4.7	4.85	4.25	4.7	3.2	2.7	3.15	3.3	11.25	4.5
14	5.0	3.9	4.4	4.8	4.4	4.4	3.2	2.7	4.1	3.0	12.35	4.2
15	4.7	4.2	4.2	4.5	5.0	4.5	3.15	2.7	4.2	3.3	11.7	4.5
16	5.3	4.3	4.1	4.6	4.2	5.4	3.1	2.7	3.1	5.1	8.8	7.3
17	5.3	4.9	3.9	4.6	4.05	5.0	3.1	2.7	3.05	5.3	9.1	5.4
18	5.15	6.2	3.95	4.3	4.05	4.75	3.0	2.7	2.9	5.2	8.65	5.0
19	4.8	7.7	3.9	4.3	4.25	4.5	3.0	2.65	2.9	4.75	6.6	5.4
20	4.5	8.1	3.8	4.3	4.2	4.35	3.0	2.65	2.8	4.35	5.9	10.6
21	4.35	7.85	3.8	4.9	4.5	4.2	2.95	2.65	2.75	3.9	6.05	9.6
22	4.5	7.05	3.8	4.7	4.5	4.2	2.95	2.65	2.7	3.7	5.5	7.2
23	6.3	6.85	3.7	4.6	4.5	3.9	2.95	2.6	2.7	3.5	5.1	6.4
24	8.55	6.4	3.95	4.5	4.3	3.9	2.9	2.6	2.95	3.4	4.9	6.4
25	6.8	6.05	3.05	5.2	4.2	3.8	2.9	2.6	3.15	3.4	4.6	6.6
26	6.25	6.4	4.2	5.2	4.3	3.75	2.85	2.6	2.9	4.2	4.4	6.6
27	5.85	6.6	4.3	4.95	4.2	3.65	2.85	2.6	2.8	4.3	4.3	6.3
28	5.5	5.95	4.25	5.2	4.1	3.65	2.85	2.6	2.8	3.85	4.0	5.45
29	5.4	....	4.25	4.95	4.35	3.65	2.8	2.6	2.75	3.8	4.0	5.2
30	5.4	....	4.65	4.9	4.6	3.85	2.8	2.6	....	3.5	3.8	5.2
31	6.1	....	6.1	....	4.35	....	2.8	2.6	....	3.4	....	5.0

NOTE.—Gage heights for May and June were affected by log jams.

Rating table for North Fork of Santiam River at Mehama, Oreg., for 1905-6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.40	590	3.40	1,570	4.40	3,100	5.80	6,410	7.80	13,750
2.50	660	3.50	1,700	4.50	3,280	6.00	7,000	8.00	14,600
2.60	740	3.60	1,840	4.60	3,470	6.20	7,630	9.00	19,200
2.70	820	3.70	1,980	4.70	3,670	6.40	8,300	10.00	24,100
2.80	910	3.80	2,130	4.80	3,880	6.60	9,000	11.00	29,100
2.90	1,000	3.90	2,280	4.90	4,100	6.80	9,730	12.00	34,300
3.00	1,100	4.00	2,430	5.00	4,330	7.00	10,500	13.00	39,800
3.10	1,210	4.10	2,590	5.20	4,810	7.20	11,290		
3.20	1,320	4.20	2,750	5.40	5,320	7.40	12,090		
3.30	1,440	4.30	2,920	5.60	5,850	7.60	12,910		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 10 discharge measurements made during 1905-1907 and is well defined between gage heights 2.5 feet and 4.5 feet.

Monthly discharge of North Fork of Santiam River at Mehama, Oreg., for 1905-6.

[Drainage area, 740 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.						
July 11-31	1,000	780	876	36,500	1.18	0.92
August	780	660	727	44,700	.982	1.13
September	3,010	625	952	56,600	1.29	1.44
October	9,730	1,500	3,460	213,000	4.68	5.40
November	3,880	1,000	1,830	109,000	2.47	2.76
December	6,700	2,430	4,010	247,000	5.42	6.25
The period				707,000		
1906.						
January	17,100	2,590	5,050	311,000	6.82	7.86
February	15,000	2,280	6,180	343,000	8.35	8.70
March	7,310	1,150	3,680	226,000	4.97	5.73
April	5,450	2,920	3,970	236,000	5.36	5.98
May	4,330	2,510	3,170	195,000	4.28	4.93
June	5,320	1,910	3,280	195,000	4.43	4.94
July	2,130	910	1,310	80,600	1.77	2.04
August	910	740	809	49,700	1.09	1.26
September	2,750	700	1,030	61,300	1.39	1.55
October	5,060	820	1,990	122,000	2.69	3.10
November	36,200	1,320	10,300	613,000	13.92	15.53
December	27,100	1,700	6,450	397,000	8.72	10.05
The year	36,200	700	3,930	2,830,000	5.31	71.67

NOTE.—Values are rated as follows: 1905, January, April, and July to December, 1906, excellent; May and June, 1906, fair; affected by log jams.

SOUTH FORK OF SANTIAM RIVER AT WATERLOO, OREG.

This station was established July 28, 1905. It is located about one-half mile below the highway bridge at Waterloo, Oreg. The station is about 4 miles above the mouth of Hamilton Creek, and about 3 miles above a dam which diverts water into a canal for the use of the town of Albany. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 225.

Discharge measurements of South Fork of Santiam River at Waterloo, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1905.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
July 28	L. R. Allen	150	246	1.06	375
1906.					
January 5	L. R. Allen	315	831	3.49	3,550
February 6	do	315	802	3.36	3,410
March 27	do	304	616	2.85	2,390
May 8	do	238	460	2.30	1,560
May 14	do	243	481	2.28	1,550
August 20	do	142	199	.93	263
September 26	I. E. Oakes	155	273	1.40	555

Daily gage height, in feet, of South Fork of Santiam River at Waterloo, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.7	4.6	4.6	4.4	3.1	3.2	2.2	1.2	0.7	1.2	2.9	2.5
2	3.2	4.4	4.2	3.7	2.4	3.0	2.1	1.2	.7	1.1	2.9	2.5
3	3.3	4.3	3.9	3.5	2.7	2.9	2.0	1.2	.7	1.5	2.9	2.4
4	3.2	3.9	3.9	3.3	2.7	3.5	1.8	1.1	.7	2.0	2.5	2.4
5	3.4	3.6	3.9	3.2	2.5	3.2	1.7	1.1	.7	1.6	2.3	2.5
6	3.5	3.4	4.0	3.1	2.4	3.6	1.8	1.1	.7	1.5	2.3	2.6
7	3.7	3.1	4.6	3.2	2.4	3.8	1.8	1.1	.7	1.3	7.4	3.5
8	3.6	3.1	4.4	3.1	2.3	4.3	1.7	1.1	.7	1.2	11.2	4.0
9	4.2	3.0	4.5	3.5	2.3	4.0	1.7	1.0	.7	1.1	6.6	3.7
10	4.0	2.9	4.2	3.2	2.3	3.4	1.6	1.0	.7	1.1	5.3	3.6
11	4.1	2.7	3.8	3.0	2.2	3.9	1.6	1.0	.7	1.0	5.6	3.6
12	4.3	2.6	3.5	2.8	2.2	3.3	1.6	1.0	.7	1.3	7.5	3.5
13	5.0	2.6	3.3	2.7	2.1	3.3	1.6	1.0	.7	1.5	10.0	3.7
14	4.4	2.6	3.2	2.6	2.3	3.1	1.5	1.0	1.8	1.3	13.5	3.3
15	4.3	3.0	2.9	2.6	2.6	3.1	1.5	1.0	1.9	1.4	10.0	4.1
16	4.6	3.0	2.7	2.7	2.8	3.7	1.5	1.0	1.7	1.5	8.5	4.0
17	5.4	3.4	2.7	2.6	2.6	3.7	1.5	1.0	1.7	4.4	8.5	3.6
18	5.0	3.8	2.6	2.5	2.6	3.2	1.5	1.0	1.7	4.0	8.2	4.5
19	4.4	5.9	2.6	2.5	2.8	3.0	1.4	1.0	1.4	4.7	8.1	7.7
20	3.9	7.0	2.5	2.5	2.7	2.7	1.4	.9	1.3	4.8	5.2	7.8
21	3.5	6.9	2.6	2.7	3.2	2.7	1.3	.8	1.2	2.3	5.1	6.5
22	3.4	5.9	2.6	2.6	3.4	2.6	1.3	.8	1.2	2.3	4.8	5.0
23	4.8	5.9	2.5	2.6	3.2	2.5	1.3	.8	1.2	2.1	4.2	4.85
24	7.1	5.9	2.6	2.6	3.0	2.4	1.3	.8	1.3	2.1	4.8	4.8
25	6.1	5.6	2.6	2.8	2.9	2.2	1.3	.8	1.3	2.3	3.5	5.6
26	5.5	5.3	2.8	3.8	2.4	2.2	1.2	.7	1.3	2.4	3.3	5.9
27	4.9	6.2	2.9	3.5	3.0	2.3	1.2	.7	1.0	2.9	3.4	4.8
28	4.5	5.1	2.8	3.7	2.9	2.3	1.2	.7	1.0	2.5	3.0	4.4
29	4.3	....	2.9	3.5	3.7	2.4	1.2	.7	1.1	2.2	2.7	4.0
30	4.5	....	2.8	3.2	3.8	2.4	1.2	.7	1.1	2.1	2.7	3.1
31	4.8	....	4.5	....	3.6	....	1.2	.7	....	2.3	....	3.8

Rating table for South Fork of Santiam River at Waterloo, Oreg., for 1905-6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.50	128	1.70	850	2.90	2,510	4.20	5,260	6.60	12,380
0.60	158	1.80	960	3.00	2,680	4.40	5,780	6.80	13,040
0.70	192	1.90	1,070	3.10	2,860	4.60	6,310	7.00	13,700
0.80	230	2.00	1,190	3.20	3,050	4.80	6,850	8.00	17,000
0.90	273	2.10	1,320	3.30	3,240	5.00	7,400	9.00	20,400
1.00	320	2.20	1,450	3.40	3,440	5.20	7,980	10.00	23,900
1.10	370	2.30	1,590	3.50	3,640	5.40	8,580	11.00	27,500
1.20	430	2.40	1,730	3.60	3,850	5.60	9,190	12.00	31,200
1.30	500	2.50	1,870	3.70	4,070	5.80	9,810	13.00	35,000
1.40	580	2.60	2,020	3.80	4,290	6.00	10,450	14.00	38,800
1.50	660	2.70	2,180	3.90	4,520	6.20	11,090		
1.60	750	2.80	2,340	4.00	4,760	6.40	11,730		

Note.—The above table is applicable only for open-channel conditions. It is based on 8 discharge measurements made during 1905-6 and is well defined between gage heights 0.9 foot and 4 feet.

Monthly discharge of South Fork of Santiam River at Waterloo, Oreg., for 1905–6.

[Drainage area, 640 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.[a]						
August	345	230	297	18,300	.464	0.54
September	1,070	158	314	18,700	.491	.55
October	6,040	660	2,340	144,000	3.66	4.22
November	3,440	580	1,270	75,600	1.98	2.21
December	7,120	2,180	4,140	255,000	6.47	7.46
The period				512,000		
1906.[b]						
January	14,000	3,050	5,790	356,000	9.05	10.43
February	13,700	2,020	5,910	328,000	9.23	9.61
March	6,310	1,870	3,490	215,000	5.45	6.28
April	5,780	1,870	2,850	170,000	4.45	4.96
May	4,290	1,320	2,310	142,000	3.61	4.16
June	5,520	1,450	2,900	173,000	4.53	5.05
July	1,450	430	707	43,500	1.10	1.27
August	430	192	298	18,300	.466	.54
September	1,070	192	411	24,500	.642	.72
October	6,850	320	1,640	101,000	2.56	2.95
November	36,900	1,590	10,300	613,000	16.09	17.95
December	16,300	1,730	5,470	336,000	8.55	9.86
The period	36,900	192	3,510	2,520,000	5.48	73.78

[a] Values for 1905 are rated as follows: October to December, excellent; August and September, good.

[b] Values for 1906 are rated as follows: March to July, September, and October, excellent; remainder of the year, good.

LUCKIAMUTE RIVER NEAR SUVER, OREG.

This station was established August 18, 1905. It is located just below Helmick bridge on the public highway, 4 miles northwest of Suver, Oreg., 2 miles west of Parkers Station, and about 3 miles below the junction of the main forks of the river. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 226.

Discharge measurements of Luckiamute River near Suver, Oreg., in 1905–6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1905.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
August 18	L. R. Allen	45	121	1.47	73
October 7	do	79	571	8.57	1,180
1906.					
January 10	P. A. Cupper	78	508	7.60	928
April 5	L. R. Allen	62	322	5.01	495
May 16	do	62	356	5.59	592
June 30	do	61	290	4.28	396

Daily gage height, in feet, of Luckiamute River near Suver, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	15.6	8.35	15.8	6.8	3.95	4.0	3.8	2.0	1.25	1.5	3.5	6.9
2	12.3	7.5	13.6	5.9	3.85	3.6	3.75	1.85	.85	1.55	2.6	6.1
3	11.25	7.3	12.05	5.3	3.65	4.0	3.5	1.8	.95	2.45	3.0	7.3
4	9.5	7.4	10.8	5.1	4.35	4.4	3.5	1.2	1.25	2.85	4.0	5.9
5	7.75	6.5	9.95	5.0	4.6	4.8	3.25	1.85	1.2	1.95	8.2	5.5
6	8.2	6.2	9.3	5.1	5.25	4.25	3.1	1.85	1.2	1.6	7.1	5.7
7	8.5	5.7	8.55	4.9	5.0	4.9	3.05	1.75	1.2	1.45	10.9	13.0
8	7.8	5.45	8.1	4.8	3.1	5.1	3.05	1.85	1.15	1.8	23.1	12.5
9	9.0	5.3	7.6	5.0	3.2	4.8	2.9	1.8	.95	1.9	23.6	11.1
10	8.3	5.2	7.4	5.8	3.05	4.35	2.85	2.15	1.25	1.7	17.6	12.8
11	9.0	5.1	7.2	5.25	3.0	4.2	2.8	1.8	1.2	1.7	18.8	12.9
12	10.8	4.9	6.75	4.35	2.9	5.1	2.7	1.75	1.35	2.5	13.0	10.9
13	17.15	4.6	6.35	4.75	3.0	5.4	2.65	1.7	2.5	3.9	15.4	10.8
14	17.15	4.5	6.1	4.3	3.2	5.6	2.6	1.75	2.3	3.2	18.7	10.3
15	16.15	4.7	6.85	3.9	3.9	5.3	2.65	1.7	2.55	3.3	22.1	12.6
16	17.6	4.9	5.4	3.83	5.6	8.7	2.25	1.75	2.5	7.5	25.9	13.0
17	20.8	6.4	5.4	3.85	6.7	7.5	2.3	1.65	1.9	8.35	23.1	12.2
18	21.6	12.3	5.3	3.75	4.2	7.2	2.5	1.6	1.75	6.5	18.9	11.5
19	18.6	18.5	5.7	3.8	4.1	6.0	2.35	1.65	1.65	5.6	15.4	13.1
20	16.55	15.5	5.95	3.8	4.25	5.6	2.5	1.45	1.55	4.8	13.0	18.0
21	15.5	23.2	6.5	3.7	4.3	5.1	2.3	1.5	1.45	3.45	12.8	22.0
22	13.2	22.0	6.6	3.6	4.4	4.6	2.2	1.55	1.3	3.6	12.6	24.5
23	16.6	21.5	7.1	3.5	3.4	4.3	2.15	1.5	1.5	3.4	11.0	18.0
24	21.6	22.5	7.3	3.5	3.8	4.25	2.15	1.4	1.65	3.1	10.0	14.0
25	18.0	23.9	7.6	4.2	4.7	4.0	2.0	1.45	2.5	2.7	9.5	13.6
26	14.8	22.9	7.45	4.1	4.9	3.95	2.5	1.45	1.8	3.2	8.3	16.0
27	13.2	22.1	7.1	4.25	5.0	3.8	2.0	1.25	1.4	5.4	7.2	13.0
28	13.5	18.9	6.5	5.25	4.85	3.65	2.3	1.3	1.3	4.5	7.3	11.9
29	10.7	....	6.8	5.35	4.6	3.9	2.25	1.2	1.7	4.2	6.4	10.2
30	10.4	....	6.1	4.2	4.45	4.3	2.5	1.15	1.95	4.1	6.5	10.5
31	9.0	....	7.5	....	4.6	....	2.35	1.3	....	4.05	....	11.4

Rating table for Luckiamute River near Suver, Oreg., for 1905–6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.90	39	2.30	143	3.70	306	6.20	701	17.00	3,770
1.00	44	2.40	153	3.80	319	6.40	737	18.00	4,148
1.10	50	2.50	163	3.90	333	6.60	774	19.00	4,540
1.20	56	2.60	173	4.00	347	6.80	812	20.00	4,944
1.30	62	2.70	184	4.20	375	7.00	850	21.00	5,360
1.40	69	2.80	195	4.40	405	8.00	1,058	22.00	5,780
1.50	76	2.90	206	4.60	435	9.00	1,290	23.00	6,200
1.60	83	3.00	218	4.80	466	10.00	1,543	24.00	6,630
1.70	91	3.10	230	5.00	498	11.00	1,810	25.00	7,060
1.80	99	3.20	242	5.20	530	12.00	2,095	26.00	7,490
1.90	107	3.30	254	5.40	563	13.00	2,400		
2.00	115	3.40	267	5.60	597	14.00	2,716		
2.10	124	3.50	280	5.80	631	15.00	3,050		
2.20	133	3.60	293	6.00	665	16.00	3,404		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 5 discharge measurements made during 1905-6 and is well defined between gage heights 1.5 feet and 9.0 feet.

Monthly discharge of Luckiamute River near Suver, Oreg., for 1905–6.

Month.	Discharge in second-feet.			Total in Acre-feet.
	Maximum.	Minimum.	Mean.	
1905.[a]				
August 26–31	76	41	55.4	1,320
September	280	39	76.6	4,560
October	1,290	133	396	24,300
November	1,000	115	247	14,700
December	4,400	375	1,450	89,200
The period				134,000
1906.[b]				
January	5,610	1,000	2,720	167,000
February	6,590	420	2,410	134,000
March	3,330	546	1,060	65,200
April	812	280	436	25,900
May	793	206	381	23,400
June	1,220	293	492	29,300
July	319	115	192	11,800
August	115	53	85	5,230
September	168	37	84.5	5,030
October	1,140	72	314	19,300
November	7,450	173	2,640	157,000
December	6,840	580	2,290	141,000
The year	7,450	37	1,090	784,000

[a] Values for 1905 are rated as follows: October, excellent; November and December, good; August and September, fair.

[b] Values for 1906 are rated as follows: April to June and October, excellent; March and July, good; remainder of the year, fair.

MOLALLA RIVER NEAR MOLALLA, OREG.

This station was established November 1, 1905. It is located at Dickey Prairie, 3 miles below the junction of the forks of the river 3½ miles southeast of Molalla, Oreg. The conditions at the station and the bench marks are described in Water-Supply Paper No. 178, page 227.

Discharge measurements of Molalla River near Molalla, Oreg., in 1905–6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
1905.					
November 2	L. R. Allen	106	226	1.83	376
1906.					
January 9[a]	L. R. Allen	130	437	3.63	1,510
January 13	P. A. Cupper	130	422	3.55	1,610
April 3	L. R. Allen	118	334	2.80	924
May 24	do	117	323	2.66	822
July 11	do	104	174	1.33	186
September 4	I. E. Oakes	102	118	.75	60

[a] Measurement unreliable.

Daily gage height, in feet, of Molalla River near Molalla, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.7	3.75	3.75	3.4	2.7	2.25	1.9	1.0	0.75	1.0	1.85	2.25
2	2.7	3.5	3.45	3.0	2.5	2.15	1.85	.95	.75	1.05	1.8	2.15
3	2.75	3.4	3.7	2.8	2.4	2.25	1.8	.95	.75	1.6	1.75	2.1
4	2.8	3.3	3.65	2.7	2.3	2.5	1.75	.95	.75	1.55	2.5	2.05
5	3.15	2.8	3.45	2.7	2.2	2.5	1.65	.9	.75	1.4	2.6	2.4
6	3.1	2.7	3.55	2.7	2.15	2.75	1.5	.9	.75	1.35	2.5	2.5
7	3.05	2.6	3.6	2.8	2.1	2.95	1.45	.9	.75	1.3	6.8	3.3
8	3.3	2.5	3.7	2.7	2.0	2.85	1.45	.9	.75	1.1	6.5	3.65
9	3.7	2.35	3.8	2.8	2.0	2.85	1.4	.9	.75	1.05	4.9	3.4
10	3.45	2.3	3.5	2.7	1.9	2.75	1.4	.9	.75	1.0	5.3	3.0
11	3.5	2.2	3.3	2.7	1.85	2.65	1.35	.9	.75	1.05	4.4	3.2
12	3.5	2.15	3.0	2.7	1.8	2.55	1.3	.85	.85	1.65	4.0	3.4
13	3.55	2.1	2.7	2.5	1.75	2.55	1.3	.85	1.3	2.2	7.45	2.8
14	3.5	2.05	2.65	2.45	2.15	2.5	1.25	.9	2.8	2.65	8.1	2.7
15	3.7	2.5	2.45	2.35	2.4	3.0	1.2	.9	2.5	2.2	8.85	3.4
16	3.9	2.5	2.3	2.35	2.35	4.0	1.2	.85	1.8	3.6	6.2	3.9
17	3.9	3.9	2.25	2.3	3.3	3.4	1.2	.85	1.45	3.9	6.0	3.2
18	3.95	5.0	2.2	2.25	2.3	3.0	1.2	.85	1.3	3.3	5.3	3.2
19	3.45	4.7	2.15	2.15	2.6	2.8	1.2	.85	1.2	3.1	4.4	3.5
20	3.1	5.9	2.1	2.1	2.7	2.6	1.15	.8	1.15	2.75	4.0	7.5
21	2.9	5.4	2.1	2.25	2.75	2.4	1.15	.8	1.15	2.5	3.8	6.0
22	2.95	4.5	2.05	2.25	2.8	2.3	1.15	.8	1.1	2.35	3.6	4.6
23	4.85	4.35	2.0	2.25	2.85	2.2	1.15	.8	1.2	2.1	3.4	4.2
24	5.2	4.5	2.2	2.2	2.65	2.1	1.1	.8	1.3	1.95	3.1	3.6
25	4.5	4.4	2.1	3.4	2.5	1.95	1.1	.8	1.2	1.9	2.9	4.2
26	4.0	4.6	2.35	3.0	2.65	1.85	1.1	.8	1.1	1.95	2.75	4.5
27	3.75	4.9	2.45	2.7	2.6	1.9	1.1	.75	1.05	1.95	2.6	3.9
28	3.5	4.35	2.4	3.1	2.5	1.95	1.1	.75	1.0	1.95	2.5	3.5
29	3.5	......	2.5	3.05	2.45	2.05	1.05	.75	.95	1.9	2.35	3.4
30	3.7	......	2.7	2.85	2.4	2.0	1.05	.75	.95	1.85	2.3	3.3
31	4.0	......	3.7	......	2.35	......	1.0	.75	......	1.85	......	3.2

Rating table for Molalla River near Molalla, Oreg., for 1905–6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.70	52	1.70	320	2.70	855	3.70	1,595	5.40	3,225
0.80	68	1.80	364	2.80	920	3.80	1,680	5.60	3.435
0.90	86	1.90	411	2.90	985	3.90	1,770	5.80	3,645
1.00	106	2.00	460	3.00	1,055	4.00	1,860	6.00	3,855
1.10	127	2.10	510	3.10	1,125	4.20	2,040	7.00	4,955
1.20	151	2.20	565	3.20	1,200	4.40	2,225	8.00	6,105
1.30	178	2.30	620	3.30	1,275	4.60	2,415	9.00	7,305
1.40	208	2.40	675	3.40	1,350	4.80	2,610		
1.50	242	2.50	735	3.50	1,430	5.00	2,810		
1.60	279	2.60	795	3.60	1,510	5.20	3,015		

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905–6 and is well defined between gage heights 0.75 foot and 4.0 feet.

Monthly discharge of Molalla River near Molalla, Oreg., for 1905–6.

[Drainage area, 220 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.[a]						
November	1,600	164	464	27,600	2.11	2.35
December	2,320	592	1,190	73,200	5.41	6.24
The period				101,000		
1906.[b]						
January	3,020	855	1,490	91,600	6.77	7.80
February	3,750	485	1,580	87,800	7.18	7.48
March	1,680	460	986	60,600	4.48	5.16
April	1,350	510	830	49,400	3.77	4.21
May	952	342	657	40,400	2.99	3.45
June	1,860	387	787	46,800	3.58	3.99
July	411	106	191	11,700	.868	1.00
August	106	60	77.6	4,770	.353	.407
September	920	60	164	9,760	.745	.831
October	1,770	106	512	31,500	2.33	2.69
November	7,120	242	2,170	129,000	9.86	11.00
December	5,530	485	1,510	92,800	6.86	7.91
The year	7,120	60	913	656,000	4.15	55.93

[a] Values for 1905 are rated as follows: November, excellent; December good.

[b] Values for 1906 are rated as follows: March to June, November and December, excellent; remainder of the year, good.

SOUTH FORK OF YAMHILL RIVER AT SHERIDAN, OREG.

This station was established April 25, 1906. It is located in Sheridan, Oreg., about 2 miles below the mouth of Mill Creek.

The channel is straight for 250 feet above and 500 feet below the station, and the current is uniform. Both banks are high and well covered with undergrowth; the right is liable to overflow at extreme high water. The bed of the stream is of sand and fine clean gravel and is liable to shift during high water. There is one channel at all stages.

Discharge measurements are made from the public highway bridge in Sheridan. The initial point for soundings is two nails driven in the wall, about 1 foot to the left of the corner of the first building on the right bank.

The gage, which is read daily by G. Schoppert, is a 2 by 8 inch timber in two sections, the lower section being vertical, 3.8 feet long, and nailed to a cross timber on the lower side of the right bridge pier. The upper portion is inclined at a small angle and nailed to an upright timber of the pier, being 24.3 feet in length. The bench mark is the top of three 30-penny nails driven in an ash tree about 5 feet below the bridge and 25 feet from the initial point; elevation, 21.70 feet above the datum of the gage.

Discharge measurements of South Fork of Yamhill River at Sheridan, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
1905.					
December 14	L. R. Allen	122	428	....	583
1906.					
April 25	L. R. Allen	124	494	2.70	813
May 18	do	123	453	2.34	625
July 1	do	116	374	1.81	436
September 7	I. E. Oakes	106	211	.30	48
October 30	do	117	309	1.80	423

Daily gage height, in feet, of South Fork of Yamhill River at Sheridan, Oreg., for 1906.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	2.0	1.9	1.9	.8	.3	....	2.0	2.5
2	....	2.0	1.8	1.65	.7	.3	....	2.0	2.5
3	....	1.9	1.8	1.5	.7	.3	....	2.0	2.4
4	....	2.3	2.9	1.5	.7	.2	....	2.0	2.3
5	....	2.3	2.9	1.45	.6	.3	....	4.0	2.3
6	....	2.2	2.9	1.45	.6	.3	....	4.3	2.3
7	....	2.1	3.1	1.4	.6	.3	....	7.9	8.5
8	....	2.9	2.8	1.4	.6	.4	....	12.0	6.0
9	....	2.8	2.75	1.3	.6	.4	....	8.1	6.0
10	....	2.7	2.4	1.3	.5	.4	....	9.0	5.5
11	....	2.6	2.5	1.3	.5	.5	....	8.0	5.5
12	....	2.5	3.0	1.35	.5	.6	....	7.8	5.3
13	....	1.7	3.9	1.2	.5	1.4	....	7.5	5.2
14	....	1.7	4.0	1.1	.6	1.6	....	8.5	4.0
15	....	2.3	3.8	1.1	.5	1.7	....	14.5	4.5
16	....	2.3	5.0	1.0	.5	1.7	....	8.5	5.5
17	....	2.5	4.0	1.0	.5	1.6	....	9.5	5.5
18	....	2.4	3.6	1.0	.5	1.0	....	8.5	4.4
19	....	2.3	3.4	1.0	.5	.9	....	7.0	4.6
20	....	2.2	3.0	1.0	.4	.7	....	7.0	11.4
21	....	2.1	2.8	.9	.4	.7	....	5.5	11.6
22	....	2.0	2.6	.9	.4	.6	....	5.3	7.3
23	....	1.9	2.4	.9	.4	.7	....	5.0	7.0
24	....	2.0	2.2	.9	.4	.9	....	4.6	5.9
25	2.6	2.5	2.0	.9	.4	1.3	....	4.0	6.8
26	2.3	2.5	1.9	.8	.4	1.0	....	4.0	5.8
27	2.4	2.9	1.9	.8	.4	.9	....	3.5	5.8
28	2.5	2.3	1.95	.8	.3	.8	....	3.0	5.3
29	2.3	2.2	1.8	.8	.3	.8	....	2.8	4.5
30	2.2	2.1	2.1	.9	.3	....	1.8	2.5	4.8
31	....	2.1	....	.8	.3	....	1.9	....	4.5

Rating table for South Fork of Yamhill River at Sheridan, Oreg., from April 25 to September 30, 1906.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.20	38	1.10	208	2.00	500	2.90	895	3.80	1,395
0.30	51	1.20	235	2.10	540	3.00	945	3.90	1,455
0.40	65	1.30	264	2.20	580	3.10	995	4.00	1,515
0.50	80	1.40	294	2.30	620	3.20	1,050	4.20	1,645
0.60	97	1.50	326	2.40	665	3.30	1,105	4.40	1,775
0.70	116	1.60	359	2.50	710	3.40	1,160	4.60	1,915
0.80	137	1.70	393	2.60	755	3.50	1,215	4.80	2,055
0.90	159	1.80	428	2.70	800	3.60	1,275	5.00	2,200
1.00	183	1.90	464	2.80	845	3.70	1,335		

Note.—The above table is applicable only for open-channel conditions. It is based on 4 discharge measurements made during 1906 and is not well defined.

Monthly discharge of South Fork of Yamhill River at Sheridan, Oreg., for 1906.

[Drainage area, 290 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
April 25-30	755	580	658	7,830	2.27	.51
May	895	303	614	37,800	2.12	2.44
June	2,200	428	873	51,900	3.01	3.36
July	464	137	225	13,800	.776	.90
August	137	51	81.0	4,980	.279	.32
September	393	38	149	8,870	.514	.57
The period				125,000		

NOTE.—The above estimates are provisional and subject to revision when more data are available. Values are rated as follows: April to June, good; July to September, fair.

CLACKAMAS RIVER NEAR BARTON, OREG.

This station was established October 2, 1905. It is located 2½ miles below Barton, Oreg., 1½ miles below the mouth of Deep Creek. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 228.

Discharge measurements of Clackamas River near Barton, Oreg., in 1905-6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
1905.					
October 2	L. R. Allen	310	704	3.30	1,600
1906.					
January 8	L. R. Allen	310	1,070	4.52	3,310
January 13	do	325	1,160	4.84	4,020
April 2	do	324	1,290	5.18	4,950
May 23	do	304	1,010	4.30	3,250
July 10	do	276	640	3.01	1,270
September 3	Ivan Oakes	265	497	2.51	817

Daily gage height, in feet, of Clackamas River near Barton, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.4	5.6	5.6	5.9	4.9	3.8	3.4	2.7	2.52	2.6	3.2	4.5
2	4.3	5.4	5.3	5.3	4.7	3.8	3.4	2.7	2.52	2.7	3.1	4.5
3	4.1	5.2	5.3	4.9	4.5	3.8	3.3	2.7	2.52	2.8	3.1	4.5
4	4.1	4.9	5.1	4.7	4.5	4.1	3.2	2.7	2.52	3.0	3.2	4.4
5	4.36	4.7	5.0	4.7	4.4	4.0	3.2	2.7	2.52	2.9	3.7	4.4
6	4.45	4.5	5.0	4.8	4.3	4.2	3.1	2.65	2.51	2.8	3.5	4.6
7	4.52	4.4	5.0	5.0	4.2	4.5	3.1	2.65	2.51	2.7	7.15	6.0
8	4.5	4.2	5.1	5.1	4.2	4.3	3.1	2.65	2.51	2.7	10.0	6.5
9	4.9	4.1	5.3	5.5	4.2	4.5	3.0	2.6	2.51	2.7	7.0	6.0
10	4.9	4.0	5.4	5.3	4.2	4.2	3.0	2.6	2.51	2.6	6.3	5.7
11	4.9	3.9	5.2	5.0	4.1	4.2	3.0	2.6	2.51	2.6	6.6	5.6
12	4.9	3.8	4.8	4.7	4.1	4.1	3.0	2.6	2.54	2.7	5.7	5.3
13	4.9	3.8	4.6	4.6	3.9	4.1	3.0	2.6	2.8	2.8	10.1	5.1
14	4.7	3.7	4.5	4.6	3.8	4.0	3.0	2.6	3.3	3.1	10.6	5.0
15	4.6	3.8	4.4	4.6	4.3	4.0	3.0	2.6	4.1	3.1	11.9	4.9
16	4.6	3.9	4.1	4.7	4.2	5.3	3.0	2.6	3.3	4.3	10.7	6.6
17	4.9	4.0	4.1	4.7	4.0	5.0	3.0	2.6	3.0	4.6	10.5	6.1
18	5.1	5.8	4.0	4.5	4.0	4.7	3.0	2.6	2.8	4.7	8.6	5.7
19	4.75	8.2	3.9	4.5	3.9	4.5	3.0	2.6	2.75	4.4	7.0	5.9
20	4.5	7.1	3.9	4.5	4.0	4.2	3.0	2.55	2.7	4.0	6.5	11.0

Daily gage height, in feet, of Clackamas River, near Barton, Oreg., for 1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
21	4.3	8.0	3.9	4.9	4.2	3.9	3.0	2.55	2.65	3.7	6.5	11.0
22	4.2	7.0	3.8	4.8	4.3	3.9	3.0	2.55	2.65	3.5	6.2	9.0
23	4.7	6.4	3.8	4.8	4.3	3.7	3.0	2.55	2.65	3.4	6.0	7.0
24	7.2	6.1	3.9	4.7	4.2	3.6	2.9	2.55	2.65	3.3	5.8	6.5
25	6.7	6.4	3.9	4.9	4.2	3.5	2.8	2.55	2.65	3.2	5.3	7.0
26	6.0	6.1	4.2	5.3	4.3	3.5	2.8	2.55	2.64	3.3	5.1	7.5
27	5.6	6.8	4.2	4.9	4.3	3.4	2.7	2.55	2.63	3.4	4.9	7.5
28	5.3	6.1	4.2	5.1	4.2	3.5	2.7	2.55	2.62	3.5	4.8	6.8
29	5.2	....	4.2	5.1	4.0	3.5	2.7	2.54	2.61	3.4	4.7	6.2
30	5.3	....	4.4	5.0	4.0	3.6	2.7	2.53	2.6	3.2	4.6	6.1
31	5.6	....	5.7	....	3.9	....	2.7	2.53	....	3.2	....	5.9

Rating table for Clackamas River near Barton, Oreg., for 1905-6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.50	810	3.50	1,860	4.50	3,480	5.50	5,560	7.00	9,460
2.60	890	3.60	2,000	4.60	3,670	5.60	5,790	7.20	10,040
2.70	970	3.70	2,140	4.70	3,860	5.70	6,030	7.40	10,620
2.80	1,060	3.80	2,290	4.80	4,050	5.80	6,270	7.60	11,220
2.90	1,160	3.90	2,450	4.99	4,250	5.90	6,510	7.80	11,820
3.00	1,260	4.00	2,610	5.00	4,460	6.00	6,760	8.00	12,430
3.10	1,370	4.10	2,780	5.10	4,670	6.20	7,270	9.00	15,530
3.20	1,480	4.20	2,950	5.20	4,890	6.40	7,790	10.00	18,730
3.30	1,600	4.30	3,120	5.30	5,110	6.60	8,330	11.00	22,030
3.40	1,730	4.40	3,300	5.40	5,330	6.80	8,890	12.00	25,430

Note.—The above table is applicable only for open-channel conditions. It is based on 7 discharge measurements made during 1905-6 and is well defined below gage height 5.5 feet.

Monthly discharge of Clackamas River near Barton, Oreg., for 1905-6.

[Drainage area, 800 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.[a]						
November 11-30	3,860	1,160	2,060	81,700	2.58	1.92
December	5.490	2,290	3,800	234,000	4.75	5.48
The period	....	....	....	316,000	....	....
1906.[b]						
January	10.000	2,780	4,400	271,000	5.50	6.34
February	13,000	2,140	5,430	302,000	6.79	7.07
March	6,030	2,290	3,700	228,000	4.62	5.33
April	6,510	3,480	4,280	255,000	5.35	5.97
May	4,250	2,290	2,960	182,000	3.70	4.27
June	5,110	1,730	2,730	162,000	3.41	3.80
July	1,730	970	1,260	77,500	1.58	1.82
August	970	834	890	54,700	1.11	1.28
September	2,780	818	1,010	60,100	1.26	1.41
October	3,860	890	1,650	101,000	2.06	2.38
November	25,100	1,370	8,720	519,000	10.90	12.16
December	22,000	3,300	7,690	473,000	9.61	11.08
The year	25,100	818	3,730	2,690,000	4.66	62.91

[a] Values for 1905 are rated as excellent.

[b] Values for 1906 are rated as follows: January to October, excellent; November and December, good.

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made in Willamette River drainage basin in 1906:

Boulder Creek near Detroit, Oreg.—The flow of this stream was estimated September 5, 1906, at 5 second-feet.

Breitenbush Creek near Detroit, Oreg.—A measurement was made at low water, September 4, 1906, just above the mouth of the creek.

Width, 59 feet; area, 100 square feet; discharge, 184 second-feet.

Calapooia Creek.—A measurement was made 300 yards below Kendall's bridge in sec. 19, T. 12 S., R. 3 W., at low water, August 23, 1906.

Width, 50 feet; area, 38 square feet; discharge, 64 second-feet.

Crabtree Creek near Thomas, Oreg.—A measurement was made 100 yards below the bridge in sec. 27, T. 10 S., R. 2 W., at low water August 24, 1906.

Width, 51 feet; area, 59 square feet; discharge, 55 second-feet.

Long Tom Creek near Junction City, Oreg.—A measurement was made 75 feet above the highway bridge, in sec. 10, T. 16 S., R. 5 W., at low water August 18, 1906.

Width, 42 feet; area, 29 square feet; discharge, 22 second-feet.

Marys Creek near Philamath, Oreg.—A measurement was made at the bridge in sec. 11, T. 12 S., R. 6 W., at low water August 25, 1906.

Width, 50 feet; area, 31 square feet; discharge, 18 second-feet.

Minto Creek.—The two channels of this stream were measured in sec. 10, T. 11 S., R. 7 E., at low water September 6, 1906.

The surface of the right channel was 3.22 feet below a spike in a large cedar just upstream from the trail crossing.

Width, 10 feet; area, 3.7 square feet; discharge, 3.7 second-feet.

The water surface of the left channel was 3.35 feet below a nail in a 10-inch cedar on the right bank just above the trail crossing.

Width, 7 feet; area, 3.3 square feet; discharge, 6.7 second-feet.

Mohawk River near Mohawk, Oreg.—A measurement was made by wading, August 16, 1906, 50 feet above the highway bridge in sec. 9, T. 17 S., R. 2 W.

Width, 62 feet; area, 64 square feet; discharge, 37 second-feet.

Permelia Creek.—A measurement was made in sec. 33, T. 10 S., R. 7 E., at low water, September 6, 1906. The water surface was 5.20 feet below a nail in a 6-inch alder 30 feet upstream from the Minto trail crossing.

Width, 39 feet; area, 32 square feet; discharge, 80 second-feet.

Roaring Creek.—This stream is very rocky and rough and has an enormous fall. A measurement was made in T. 11 S., R. 7 E., at low water, September 7, 1906. The water surface was 3.84 feet below a spike in an 18-inch alder on the right bank near the Minto trail crossing.

Width, 19 feet; area, 26 square feet; discharge, 65 second-feet.

Santiam River at Jefferson, Oreg.—This station is described in Water-Supply Paper 178, page 224. Gage readings were discontinued during 1906, as the flow was obstructed by logs. The following measurements were made during 1906:

January 3, width, 314 feet; area, 3,060 square feet; gage height, 4.76 feet; discharge, 5,790 second-feet.

March 30, width, 311 feet; area, 2,950 square feet; gage height, 5.50 feet; discharge, 6,170 second-feet.

Marion Fork of Santiam River.—A measurement was made in sec. 15, T. 11 S., R. 7 E., at low water, September 6, 1906. The water surface was 4.76 feet below a spike in a yew tree on the right bank, 30 feet upstream from the foot log.

Width, 52 feet; area, 91 square feet; discharge, 157 second-feet.

A measurement was made September 7, 1906, 200 feet below the outlet of Lake Marion. The water surface was 4.45 feet below a spike in a small alder, on the right bank 30 feet downstream from water-right notice.

Width, 31 feet; area, 51 square feet; discharge, 77 second-feet.

Middle Fork of Santiam River.—The following measurement was made near Foster, Oreg., at low water, September 3, 1906.

Width, 96 feet; area, 183 square feet; discharge, 66 second-feet.

The following measurement was made at Withcombe Place, Oreg., at low water, September 4, 1906.

Width, 60 feet; area, 144 square feet; discharge, 82 second-feet.

North Fork of North Fork of Santiam River near Mehama, Oreg.—A measurement was made in sec. 18, T. 9 S., R. 2 E., at old fort one-half mile above Mehama, at low water, August 21, 1906.

Width, 59 feet; area, 40 square feet; discharge, 54 second-feet.

North Fork of Santiam River in sec. 12, T. 10 S., R. 5 E.—A measurement was made at low water, August 22, 1906, opposite the mill above Detroit, Oreg.

Width, 58 feet; area, 387 square feet; discharge, 469 second-feet.

A measurement was made September 4, 1906, below the mouth of Breitenbush Creek. The water surface was 3.68 feet below a spike in the upstream face of the foot log near the right bank.

Width, 110 feet; area, 282 square feet; discharge, 564 second-feet.

A measurement was made September 5, 1906, above the mouth of Breitenbush Creek. The water surface was 5.95 feet below a shelf cut into rock on the right bank for a brace to the footbridge.

Width, 60 feet; area, 456 square feet; discharge, 433 second-feet.

North Fork of Santiam River T. 11 S., R. 7 E.—A measurement was made above the mouth of Marion Fork, September 6, 1906, at low water.

East channel, width, 30 feet; area, 45 square feet; discharge, 43 second-feet. West channel, width, 36 feet; area, 44 square feet; discharge, 53 second-feet.

South Fork of Santiam River.—A measurement was made 150 yards below Sanderson bridge in sec. 4, T. 11 S., R. 2 W., on August 24, 1906.

Width, 76 feet; area, 50 square feet; discharge, 51 second-feet.

A measurement was made at Foster, September 3, 1906.

Width, 87 feet; area, 163 square feet; discharge, 131 second-feet.

A measurement was made at Withcombe Place, September 3, 1906.

Width, 60 feet; area, 144 square feet; discharge, 82 second-feet.

Thomas Fork of Santiam River at Scio, Oreg.—A measurement was made above the bridge in sec. 18, T. 10 S., R. 1 W., August 24, 1906.

Width, 34 feet; area, 28 square feet; discharge, 28 second-feet.

Whitewater Creek in SW. ¼ sec. 21, T. 10 S., R. 7 E.—A measurement was made one-fourth mile above the mouth September 6, 1906. The water surface was 4.49 feet below the reference point on a cedar tree 100 feet upstream from a log cabin near the Minto trail.

Width, 32 feet; area, 28 square feet; discharge, 65 second-feet.

PUGET SOUND DRAINAGE BASIN.

DESCRIPTION OF BASIN.

The streams flowing into Puget Sound drain the western slope of the Cascade Mountains in Washington. Their areas are heavily timbered and mountainous. The precipitation is high, varying from 40 to 100 inches per annum. The streams draining this area are principally valuable for power and logging purposes. Little or no irrigation is practiced.

SNOHOMISH RIVER DRAINAGE BASIN.

SNOQUALMIE RIVER NEAR SNOQUALMIE FALLS, WASH.

Snoqualmie and Skykomish rivers unite to form Snohomish River, which flows into Puget Sound about 10 miles beyond the junction, near Everett, Wash. The following gage heights were furnished by the Seattle-Tacoma Power Company, of Seattle, Wash. The gage is referred to mean sea datum and is not the one referred to in Water-Supply and Irrigation Paper No. 178, page 233.

Daily gage height, in feet, of Snoqualmie River near Snoqualmie Falls, Wash., for 1906.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1	561.8	561.2	12	565.9	561.9	23	561.9	563.6
2	561.3	561.6	13	566.6	561.9	24	561.7	562.9
3	561.1	561.3	14	570.0	561.3	25	561.5	562.8
4	561.6	561.5	15	570.2	561.5	26	561.5	562.0
5	561.7	562.0	16	570.0	562.0	27	561.6	561.8
6	561.9	562.4	17	564.2	562.8	28	561.6	561.7
7	562.8	563.0	18	563.4	562.5	29	561.6	561.7
8	562.6	562.4	19	562.9	563.0	30	561.6	561.7
9	563.0	562.4	20	562.4	564.6	31	....	561.7
10	564.5	561.9	21	562.3	564.5			
11	563.0	561.9	22	562.2	563.9			

WHITE RIVER DRAINAGE BASIN.

White River rises near Mount Rainier and flows into Puget Sound near Seattle. Cedar River is a branch of White River.

CEDAR RIVER NEAR RAVENSDALE, WASH.

This station was established September 27, 1902. It is located at the intake of the Seattle waterworks pipe line and is 15 miles below Cedar Lake, 4 miles from the Northern Pacific Railway at Ravensdale, and 6 miles from the Columbia and Puget Sound Railway at Maple Valley. The discharge of the pipe line is practically constant at 34 second-feet. The conditions at this station and the bench marks are described in Water-Supply Paper No. 178, page 230, where are given also references to publications that contain data for previous years.

The following measurement was made October 21, 1906:

Width, 128 feet; area, 1,060 square feet; gage height, 1.40 feet; discharge, 864 second-feet.

Daily gage height, in feet, of Cedar River near Ravensdale, Wash., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.30	2.18	1.56	1.39	1.30	1.13	1.09	0.62	0.55	0.58	1.38	1.17
2	1.26	2.14	1.47	1.41	1.31	1.15	1.07	.63	.57	.60	1.32	1.88
3	1.21	2.07	1.39	1.36	1.27	1.07	1.04	.62	.57	.62	1.20	1.08
4	1.31	1.96	1.31	1.29	1.26	1.18	1.01	.63	.56	.66	1.18	1.07
5	1.48	1.92	1.28	1.26	1.21	1.12	.97	.35	.57	.62	1.12	1.09
6	1.83	1.77	1.26	1.27	1.16	1.14	.93	.65	.57	1.20	1.08	1.25
7	1.76	1.64	1.27	1.33	1.13	1.15	.90	.63	.59	1.14	1.21	1.64
8	1.76	1.56	1.30	1.37	1.10	1.12	.89	.62	.60	1.00	1.40	1.70
9	1.71	1.47	1.35	1.48	1.10	1.11	.87	.61	.59	1.06	1.50	1.64
10	1.64	1.42	1.41	1.42	1.13	1.10	.86	.61	.58	1.14	1.71	1.57
11	1.51	1.36	1.40	1.36	1.10	1.12	.82	.60	.58	1.25	2.00	1.44
12	1.47	1.31	1.37	1.33	1.08	1.13	.82	.60	.61	1.32	2.20	1.36
13	1.45	1.29	1.30	1.26	1.09	1.12	.82	.60	.64	1.35	3.64	1.27
14	1.37	1.26	1.25	1.22	1.08	1.11	.77	.61	.72	1.42	6.77	1.26
15	1.31	1.20	1.20	1.19	1.04	1.13	.75	.60	.64	1.43	8.65	1.27
16	1.28	1.18	1.19	1.18	1.13	1.21	.74	.59	.60	1.55	6.35	1.64
17	1.29	1.20	1.16	1.21	1.11	1.16	.72	.60	.58	1.60	4.10	1.65
18	1.25	1.31	1.14	1.21	1.06	1.12	.72	.59	.59	1.54	3.11	1.62
19	1.21	1.92	1.10	1.20	1.07	1.15	.69	.60	.57	1.41	2.55	1.72
20	1.17	1.99	1.07	1.19	1.05	1.09	.68	.60	.57	1.40	2.22	2.73

Daily gage height, in feet, of Cedar River near Ravensdale, Wash., for 1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
21	1.15	2.06	1.05	1.27	1.04	1.12	.67	.59	.56	1.29	2.10	3.02
22	1.23	1.95	1.05	1.37	1.04	1.14	.66	.58	.55	1.20	1.91	2.85
23	1.68	1.85	1.04	1.44	1.08	1.12	.65	.57	.57	1.15	1.71	2.52
24	2.25	1.84	1.02	1.38	1.07	1.06	.65	.59	.60	1.06	1.58	2.20
25	2.67	1.76	1.01	1.35	1.02	1.05	.63	.58	.59	1.25	1.52	2.02
26	2.47	1.78	1.01	1.31	1.06	1.04	.63	.58	.58	2.11	1.47	1.83
27	2.25	1.71	1.07	1.28	1.04	1.01	.66	.56	.58	2.24	1.39	1.77
28	2.10	1.67	1.04	1.26	1.06	1.01	.65	.58	.57	1.94	1.24	1.64
29	2.01	....	1.03	1.25	1.03	1.13	.63	.57	.57	1.73	1.18	1.60
30	2.00	....	1.04	1.27	1.02	1.11	.64	.57	.57	1.59	1.77	1.50
31	2.10	....	1.29	....	1.14	....	.63	.57	....	1.47	....	1.45

NOTE.—These gage heights were read with a hook gage and give the height above the crest of the diversion dam of the Seattle water-system pipe line

Rating table for Cedar River near Ravensdale, Wash., for 1905–6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.50	180	1.60	910	2.70	1,940	3.70	3,100	5.40	5,450
0.60	230	1.70	990	2.80	2,050	3.80	3,220	5.60	5,750
0.70	285	1.80	1,075	2.90	2,160	3.90	3,350	5.80	6,050
0.80	340	1.90	1,160	3.00	2,270	4.00	3,480	6.00	6,370
0.90	400	2.00	1,250	3.10	2,380	4.20	3,740	6.20	6,690
1.00	465	2.10	1,340	3.20	2,500	4.40	4,000	6.40	7,010
1.10	530	2.20	1,430	3.30	2,620	4.60	4,280	6.60	7,330
1.20	600	2.30	1,530	3.40	2,740	4.80	4,560	6.80	7,660
1.30	675	2.40	1,630	3.50	2,860	5.00	4,850	7.00	8,000
1.40	750	2.50	1,730	3.60	2,980	5.20	5,150	8.00	9,700
1.50	830	2.60	1,830						

NOTE.—The above table is computed for discharges over a steel-shod triangular weir 120 feet long, which approximates in shape type O in Hazen and Whipple's discussion of irregular weirs. It includes the discharge of the Seattle water-supply pipe line.

Monthly discharge of Cedar River near Ravensdale, Wash., for 1905–6.

[Drainage area, 170 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.						
January	1,010	376	623	38,300	3.66	4.22
February	1,010	280	535	29,700	3.15	3.28
March	1,070	420	742	45,600	4.36	5.03
April	870	485	618	36,800	3.64	4.06
May	1,980	406	807	49,600	4.75	5.48
June	1,190	394	656	39,000	3.86	4.31
July	472	274	336	20,700	1.98	2.28
August	268	180	236	14,500	1.39	1.60
September	246	195	215	12,800	1.26	1.41
October	1,230	180	710	43,700	4.18	4.82
November	950	290	478	28,400	2.81	3.14
December	1,070	524	728	44,800	4.28	4.93
The year	1,980	180	557	404,000	3.28	44.56
1906.						
January	1,910	565	950	58,400	5.59	6.44
February	1,410	586	976	54,200	5.74	5.98
March	878	472	610	37,500	3.59	4.14
April	814	586	678	40,300	3.99	4.45
May	682	478	538	33,100	3.16	3.64
June	608	472	540	32,100	3.18	3.55
July	524	246	334	20,500	1.96	2.26
August	258	210	231	14,200	1.36	1.57
September	296	205	224	13,300	1.32	1.47
October	1,470	220	688	42,300	4.05	4.67
November	10,800	517	1,870	111,000	11.00	12.27
December	2,290	510	1,010	62,100	5.95	6.86
The year	10,800	205	721	519,000	4.24	57.30

NOTE.—Values for 1905–6 are rated as good. Discharge includes 34 second-feet diverted by the Seattle water supply pipe line.

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made in Puget Sound drainage basin during 1906:

Baker River near Baker, Wash.—A measurement was made November 5, 1906, at the highway bridge between Baker and Concrete. The water surface was 24.25 feet below the top of the first floor beam from the left downstream pier. The stage was about 3 feet above low water, and 15 feet below high water.

Width, 150 feet; area, 737 square feet; discharge, 3,180 second-feet.

Creeks near Baker, Wash.—The discharge of the first creek below the head-gate of the Washington Portland Cement Company's power flume was estimated November 5, 1906, as 8 second-feet. This stream is a series of cascades. The discharge of the second from the head-gate was estimated as 6 second-feet.

Carbon River.—This stream rises in Mount Rainier and flows into Puyallup River. It is a glacial stream and is always white with suspended matter. A measurement was made near the mouth of Canada Creek, September 26, 1906, which was not low water for the season.

Width, 31 feet; area, 54 square feet; discharge, 145 second-feet.

A measurement was made September 27, 1906, at the railroad bridge at Fairfax, Wash. The water surface was 8.55 feet below the top of the retaining wall forming the right abutment downstream side.

Width, 54 feet; area, 103 square feet; discharge, 455 second-feet.

Canada Creek.—This stream is a tributary of Carbon River. A measurement was made near the mouth September 26, 1906. The water surface was 3.52 feet below a nail in a small cedar near the mouth.

Width, 7 feet; area, 3.2 square feet; discharge, 5.5 second-feet.

Chenuis Creek.—A measurement was made near the junction with Carbon River, September 27, 1906.

Width, 14 feet; area, 14 square feet; discharge, 15 second-feet.

NORTHERN PACIFIC OCEAN DRAINAGE.

DESCRIPTION OF BASIN.

The streams draining the western slope of the Coast Range in Oregon are comparatively short, but, owing to the heavy precipitation on their catchment basins, carry large quantities of water. The area throughout this region is mountainous and heavily timbered. A considerable portion of the timbered area has been burned over. The principal streams in this basin are the Siletz, Alseya, Suislaw, Smiths, Umpqua, Coquille, Illinois, and Rogue rivers.

SILETZ RIVER BASIN.

SILETZ RIVER AT SILETZ, OREG.

This station was established November 25, 1905. It is located at Siletz, Oreg., about 1 mile above the ferry on the Siletz and Toledo stage road, 6 miles below the mouth of Rock Creek. The conditions at this station and the bench marks are described in Water-Supply Paper No. 177, page 252.

Discharge measurements of Siletz River at Siletz, Oreg., in 1905-6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
1905.					
November 26	L. R. Allen	157	394	2.15	1,170
1906.					
February 9	L. R. Allen	156	338	1.77	810
March 29	do	157	370	2.03	1,030
May 10	do	157	303	[a]1.50	492
July 23	do	151	231	1.23	309
September 24	I. E. Oakes	155	289	1.60	592

[a] Possible backwater effect from small dam 75 feet below.

Daily gage height, in feet, of Siletz River at Siletz, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.5	2.5	3.6	2.3	1.9	1.9	2.1	1.15	0.85	1.4	2.0	2.0
2	3.8	2.4	3.0	2.2	1.85	1.85	2.0	1.1	.85	1.5	2.0	2.0
3	3.3	2.3	2.7	2.1	1.8	1.9	1.85	1.1	.85	1.8	2.2	2.0
4	3.0	2.2	2.9	2.0	1.75	2.3	1.8	1.1	.85	1.7	3.0	2.7
5	2.9	2.1	2.9	1.95	1.7	2.6	1.75	1.1	.85	1.6	3.4	2.9
6	2.8	2.0	2.9	1.9	1.65	2.7	1.65	1.1	.85	1.6	3.7	6.2
7	2.7	1.9	2.7	1.8	1.6	2.65	1.6	1.05	.85	1.5	10.74	4.2
8	2.9	1.8	2.6	1.75	1.6	2.6	1.55	1.05	.95	1.5	12.5	4.0
9	2.9	1.8	2.5	2.2	1.55	2.55	1.5	1.05	.95	1.45	7.1	3.7
10	2.8	1.7	2.4	2.0	1.55	2.6	1.5	1.05	.9	1.6	9.1	3.5
11	3.0	1.7	2.3	1.9	1.5	2.6	1.45	1.0	.9	2.0	6.3	3.5
12	3.6	1.6	2.1	1.85	1.5	2.7	1.4	1.0	.95	1.9	7.0	3.1
13	5.8	1.6	2.1	1.8	1.5	3.35	1.4	1.0	1.6	1.85	8.4	3.0
14	4.8	1.5	2.0	1.75	2.0	3.1	1.4	1.0	2.0	1.85	13.5	2.8
15	4.2	1.5	1.9	1.7	2.4	3.05	1.35	1.0	1.95	2.65	16.6	3.0
16	5.0	1.8	1.8	1.7	2.65	4.1	1.35	1.0	1.5	4.0	9.9	4.0
17	5.8	2.8	1.8	1.65	2.4	3.55	1.3	.95	1.35	3.9	9.7	3.7
18	5.6	6.6	1.8	1.6	2.3	3.1	1.3	.95	1.25	3.6	7.6	3.5
19	4.8	6.05	1.8	1.6	2.2	2.8	1.3	.95	1.15	3.1	5.5	4.1
20	4.0	7.6	1.9	1.55	2.2	2.6	1.3	.95	1.15	2.7	4.4	11.5
21	3.5	7.9	2.1	1.5	2.3	2.4	1.25	.95	1.1	2.6	4.1	12.9
22	3.8	6.9	2.1	1.5	2.2	2.25	1.25	.95	1.1	2.4	3.7	7.0
23	6.2	5.8	2.3	1.5	2.1	2.1	1.25	.9	1.4	2.25	3.5	5.1
24	8.1	6.4	2.4	2.35	2.0	2.0	1.25	.9	1.6	2.1	3.2	4.0
25	5.7	6.7	2.3	2.15	2.05	1.95	1.2	.9	1.6	2.5	2.9	3.8
26	4.4	6.4	2.2	2.2	2.3	1.9	1.2	.9	1.5	3.3	2.7	3.6
27	3.7	6.4	2.2	2.2	2.25	1.8	1.2	.9	1.5	3.0	2.5	3.45
28	3.2	4.7	2.1	2.2	2.2	1.8	1.2	.9	1.4	2.7	2.4	3.15
29	2.9	....	2.0	2.1	2.1	2.2	1.2	.9	1.4	2.55	2.3	3.0
30	2.6	....	2.1	2.0	2.05	2.4	1.15	.9	1.4	2.4	2.1	3.0
31	2.6	....	2.3	....	2.0	....	1.15	.85	....	2.2	....	2.9

Rating table for Siletz River at Siletz, Oreg., for 1906.

Gage height.	Discharge	Gage height.	Discharge	Gage height.	Discharge.	Gage height.	Discharge	Gage height.	Discharge
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.85	130	1.40	425	2.00	990	2.60	1,790	3.40	3,070
0.90	150	1.50	500	2.10	1,110	2.70	1,940	3.60	3,410
1.00	195	1.60	580	2.20	1,230	2.80	2,090	3.80	3,770
1.10	245	1.70	670	2.30	1,360	2.90	2,250	4.00	4,130
1.20	300	1.80	770	2.40	1,500	3.00	2,410		
1.30	360	1.90	880	2.50	1,640	3.20	2,730		

NOTE.—The above table is applicable only for open-channel conditions. It is based on 5 discharge measurements made during 1905–6 and is well defined between gage heights 1.2 feet and 2.2 feet.

Monthly discharge of Siletz River at Siletz, Oreg., for 1906.

[Drainage area, 220 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
March	3,410	770	1,430	87,900	6.50	7.49
April	1,430	500	899	53,500	4.09	4.56
May	1,860	500	990	60,900	4.50	5.19
June	4,310	770	1,700	101,000	7.73	8.62
July	1,110	272	467	28,700	2.12	2.44
August	272	130	191	11,700	.868	1.00
September	990	130	345	20,500	1.57	1.75
October	4,130	425	1,480	91,000	6.73	7.76
November 1–7	3,590	990	1,750	24,300	7.95	2.07
The period				480,000		

NOTE.—The above estimates are provisional and subject to revision when more data are available. Values are rated as follows: April, May, and July, excellent; March, June, and August to November, good.

UMPQUA RIVER DRAINAGE BASIN.

UMPQUA RIVER AT ELKTON, OREG.

This station was established October 18, 1905, by J. G. Kelley, of Portland, Oreg., by whom it is maintained and the results furnished to the Geological Survey. It is located at Smiths Ferry, 4 miles above Elkton.

The gage is 100 feet above the ferry, on the left bank. It is an inclined staff fastened to bed rock. The gage datum is low water.

The following measurement was made August 11, 1906:

Width, 365 feet; area, 1,560 square feet; gage height, 0.07 foot; discharge, 1,340 second-feet.

Daily gage height, in feet, of Umpqua River near Elkton, Oreg., for 1905–6.

1905.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1		0.08	2.88	12		0.00	1.67	23	.08	.62	2.54
2		.00	2.38	13		.00	1.38	24	.08	.42	2.12
3		.00	2.00	14		.00	1.21	25	.17	.29	1.42
4		.00	2.33	15		.00	1.12	26	.17	.25	1.75
5		.00	2.42	16		.00	1.05	27	.67	.25	6.00
6		.00	2.67	17		.00	.08	28	.71	1.42	5.71
7		.00	3.12	18	0.08	.00	1.21	29	.58	1.29	4.46
8		.00	3.08	19	.75	.00	1.42	30	.58	1.88	4.08
9		.00	2.88	20	.50	.50	2.33	31	.38		8.29
10		.00	2.38	21	.42	1.62	4.29				
11		.00	1.96	22	0.25	1.21	3.29				

Daily gage height, in feet, of Umpqua River near Elkton, Oreg., for 1905-6—Continued.

1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.08	5.50	7.50	7.33	3.58	6.29	1.75	0.25	0.00	0.00	0.00	1.38
2	6.08	5.00	6.17	6.58	3.29	5.46	1.75	.25	.00	.00	.00	1.29
3	3.38	4.42	6.05	5.71	3.12	4.88	1.67	.17	.00	.00	.00	1.12
4	3.46	4.50	5.75	5.29	3.00	4.88	1.50	.17	.00	.00	.00	1.00
5	3.46	4.12	5.75	5.29	3.00	4.83	1.38	.17	.00	.00	.25	1.00
6	3.38	3.79	5.05	4.62	3.05	4.58	1.33	.17	.00	.00	.12	1.05
7	3.50	3.54	5.25	4.33	2.96	4.79	1.17	.17	.00	.00	1.50	1.42
8	3.50	3.29	5.25	4.17	2.75	4.88	1.00	.17	.00	.00	3.75	3.08
9	4.29	3.17	5.21	4.05	2.75	4.83	1.00	.17	.00	.00	3.75	5.21
10	6.88	3.05	5.12	4.17	2.58	4.83	.88	.17	.00	.00	3.12	5.58
11	5.62	2.96	5.00	3.88	2.75	5.38	.75	.17	.00	.00	2.25	5.75
12	5.29	2.79	5.00	3.54	2.71	4.75	.75	.17	.00	.08	2.21	5.21
13	9.88	2.62	5.00	3.21	2.58	4.50	.75	.17	.00	.12	1.96	4.62
14	8.88	2.50	5.00	3.12	2.46	4.08	.75	.08	.29	.08	2.33	3.88
15	8.17	2.62	4.17	3.00	2.54	4.25	.75	.08	1.17	.12	2.92	3.54
16	13.79	3.08	3.12	3.00	4.12	4.42	.62	.08	1.00	.21	6.33	5.62
17	18.33	3.25	3.00	3.00	3.96	4.50	.54	.08	.75	.29	5.50	6.33
18	10.42	3.67	3.00	2.96	3.58	3.96	.50	.00	.54	1.21	7.17	4.75
19	8.46	6.88	3.00	2.67	3.38	3.62	.50	.00	.46	1.12	5.83	4.67
20	6.79	9.05	3.00	2.67	3.08	3.29	.50	.00	.42	1.00	4.50	6.05
21	5.88	15.38	3.50	2.75	2.96	3.00	.46	.00	.33	.67	4.00	6.67
22	5.21	13.08	4.17	2.88	3.46	2.92	.42	.00	.25	.38	4.58	5.42
23	5.05	11.62	4.50	3.08	4.46	2.67	.42	.00	.12	.29	4.58	4.79
24	8.62	11.33	4.29	3.08	4.21	2.42	.33	.00	.08	.00	3.50	4.42
25	8.29	11.38	4.17	3.08	3.46	2.25	.25	.00	.17	.00	3.05	5.21
26	7.58	9.75	4.29	3.17	3.75	2.17	.25	.00	.17	.00	2.67	8.21
27	6.62	10.88	4.46	3.33	3.88	2.00	.25	.00	.05	.00	2.29	8.21
28	5.83	8.62	4.12	3.75	4.58	2.00	.25	.00	.00	.00	2.00	6.75
29	5.38	....	3.96	4.00	13.21	2.00	.25	.00	.00	.00	1.88	5.33
30	4.54	....	3.75	3.88	10.25	1.96	.25	.00	.00	.00	9.67	4.79
31	5.42	....	3.75	.....	8.50	......	.25	.00	.....	.00	....	5.62

NORTH FORK OF UMPQUA RIVER NEAR OAKCREEK, OREG.

This station was established September 6, 1905. It is located 3 miles west of Oakcreek, Oreg., 1¼ miles above J. R. Dixon's farmhouse, about 10 miles below the mouth of East Fork of North Fork of Umpqua River. The conditions at the station and the bench marks are described in Water-Supply Paper No. 177, page 251.

Discharge measurements of North Fork of Umpqua River near Oakcreek, Oreg., in 1905-6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
1905.					
September 6	L. R. Allen	215	457	1.35	886
October 19	....do	222	580	2.10	1,420
December 27	....do	279	1,450	5.35	7,110
1906.					
January 31	L. R. Allen	280	1,480	5.56	7,370
March 20	....do	249	847	3.23	2,780
May 1	....do	268	1,090	4.06	4,340
May 30	....do	284	1,800	6.74	10,200
July 14	....do	213	611	2.23	1,600
August 10	....do	190	508	1.73	1,120
September 13	....do	208	604	2.30	1,610

Daily gage height, in feet, of North Fork of Umpqua River near Oakcreek, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.6	5.2	5.3	5.5	4.05	5.0	2.9	1.8	1.5	1.5	1.5	2.4
2	3.2	5.0	4.75	5.5	3.9	4.7	2.8	1.8	1.5	1.5	1.55	2.35
3	3.1	4.7	4.6	5.1	3.9	4.5	2.8	1.8	1.5	1.55	1.6	2.3
4	3.4	4.3	4.4	4.6	3.95	4.45	2.6	1.8	1.5	1.6	1.8	2.3
5	3.7	4.15	4.3	4.4	3.8	4.3	2.6	1.8	1.5	1.55	2.8	2.45
6	3.7	4.1	4.2	4.2	3.7	4.5	2.6	1.8	1.5	1.5	2.25	2.5
7	3.7	4.1	4.9	4.0	3.65	4.95	2.5	1.75	1.5	1.5	6.25	4.5
8	3.8	4.1	5.0	3.8	3.6	5.2	2.45	1.75	1.6	1.45	4.35	4.55
9	7.3	3.7	5.0	4.4	3.65	5.5	2.4	1.7	1.7	1.45	3.75	4.7
10	5.2	3.6	4.75	4.4	3.75	5.05	2.35	1.7	1.6	1.45	3.3	4.4
11	5.4	3.5	4.3	3.85	3.7	5.5	2.35	1.7	1.5	1.5	3.3	4.2
12	5.55	3.4	4.15	3.65	3.55	4.5	2.3	1.7	1.65	1.8	2.8	4.2
13	6.2	3.3	3.7	3.55	3.5	4.5	2.25	1.7	2.4	1.7	3.8	3.7
14	6.1	3.3	3.5	3.55	3.5	4.3	2.2	1.65	2.3	1.75	4.1	3.55
15	5.4	3.7	3.25	3.65	4.1	4.4	2.2	1.65	2.5	1.65	7.75	4.35
16	12.5	3.6	3.25	3.7	4.0	4.3	2.25	1.65	1.95	2.1	5.75	6.15
17	7.0	3.85	3.0	3.6	3.8	4.5	2.15	1.65	1.75	3.0	7.1	5.0
18	6.7	4.6	3.15	3.5	3.6	4.1	2.1	1.6	1.65	2.9	6.1	4.4
19	6.3	6.75	3.1	3.5	3.55	3.95	2.1	1.6	1.5	2.9	4.6	4.4
20	4.3	7.3	4.8	3.75	3.95	3.8	2.05	1.6	1.55	2.9	4.1	6.15
21	4.0	7.5	4.4	3.9	4.5	3.6	1.9	1.6	1.55	1.85	4.9	6.9
22	8.95	6.95	4.15	3.95	4.9	3.3	2.0	1.6	1.55	1.85	4.4	5.7
23	5.6	6.55	3.8	3.95	4.6	3.0	1.95	1.6	1.6	1.85	3.95	4.95
24	7.4	6.95	4.3	3.7	4.8	3.3	1.95	1.55	1.8	1.7	3.6	5.2
25	6.7	6.4	4.2	3.85	4.0	3.2	1.95	1.55	1.6	1.65	3.3	6.85
26	6.06	6.4	4.2	4.05	4.0	3.1	1.9	1.55	1.6	1.6	3.0	7.4
27	5.4	7.25	4.1	4.2	5.8	3.1	1.9	1.5	1.55	1.75	2.8	5.9
28	5.1	7.0	3.9	4.45	7.5	3.05	1.9	1.5	1.55	1.65	2.7	5.0
29	4.7	......	3.7	4.3	7.9	3.0	1.9	1.5	1.5	1.6	2.6	4.9
30	5.2	......	3.9	4.2	6.75	2.9	1.9	1.5	1.5	1.65	2.5	4.8
31	5.2	......	5.9	......	5.6	......	1.85	1.5	......	1.6	......	4.8

Rating table for North Fork of Umpqua River near Oakcreek, Oreg., for 1905–6.

Gage height.	Discharge.	Gage height.	Discharge	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.30	860	2.50	1,860	3.70	3,580	4.90	5,930	7.20	11,340
1.40	920	2.60	1,980	3.80	3,760	5.00	6,150	7.40	11,860
1.50	985	2.70	2,100	3.90	3,940	5.20	6,590	7.60	12,390
1.60	1,055	2.80	2,230	4.00	4,130	5.40	7,040	7.80	12,930
1.70	1,130	2.90	2,360	4.10	4,320	5.60	7,500	8.00	13,470
1.80	1,205	3.00	2,500	4.20	4,510	5.80	7,960	9.00	16,300
1.90	1,285	3.10	2,640	4.30	4,700	6.00	8,420	10.00	19,300
2.00	1,370	3.20	2,780	4.40	4,900	6.20	8,900	11.00	22,300
2.10	1,460	3.30	2,930	4.50	5,100	6.40	9,380	12.00	25,300
2.20	1,550	3.40	3,080	4.60	5,300	6.60	9,860		
2.30	1,650	3.50	3,240	4.70	5,510	6.80	10,340		
2.40	1,750	3.60	3,410	4.80	5,720	7.00	10,830		

Note.—The above table is applicable only for open-channel conditions. It is based on 10 discharge measurements made during 1905–6 and is well defined between gage heights 1.3 feet and 7.0 feet.

Monthly discharge of North Fork of Umpqua River near Oakcreek, Oreg., for 1905–6.

[Drainage area, 1,000 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.						
September 6–30	1,090	860	902	44,700	0.902	0.839
October	2,300	920	1,270	78,100	1.27	1.46
November	2,230	890	1,190	70,800	1.19	1.33
December	9,020	1,650	3,020	186,000	3.02	3.48
The period				380,000		
1906.						
January	26,800	2,640	7,600	467,000	7.60	8.76
February	12,100	2,930	6,490	360,000	6.49	6.76
March	8,190	2,500	4,570	281,000	4.57	5.27
April	7,270	3,240	4,340	258,000	4.34	4.84
May	13,200	3,240	5,000	307,000	5.00	5.76
June	7,270	2,360	4,470	266,000	4.47	4.99
July	2,360	1,240	1,600	98,400	1.60	1.84
August	1,200	985	1,090	67,000	1.09	1.26
September	1,860	985	1,120	66,600	1.12	1.25
October	2,500	952	1,260	77,500	1.26	1.45
November	12,800	985	4,120	245,000	4.12	4.60
December	11,900	1,650	5,500	338,000	5.50	6.34
The year	26,800	952	3,930	2,830,000	3.93	53.12

NOTE.—Values for 1905 and 1906 are excellent.

SOUTH FORK OF UMPQUA RIVER NEAR BROCKWAY, OREG.

This station was established December 6, 1905, by L. R. Allen. It is located just below Winston's highway bridge, 3 miles east of Brockway, Oreg., and 3 miles below the mouth of Lookingglass Creek. The conditions at this station and the bench marks are described in Water-Supply Paper No. 177, page 250.

Discharge measurements of South Fork of Umpqua River near Brockway, Oreg., in 1905–6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
1905.					
December 28	L. R. Allen	302	1,620	4.16	3,000
1906.					
February 1	L. R. Allen	303	1,650	4.32	3,490
March 21	do	299	1,440	3.60	2,390
May 2	do	295	1,200	2.82	1,500
May 29	do	320	3,130	8.77	14,800
May 29	do	318	2,920	8.40	13,800
July 13	do	283	688	.95	442
August 9	do	276	481	.22	205
September 14	I. E. Oakes	284	642	.78	414

Daily gage height, in feet, of South Fork of Umpqua River near Brockway, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.4	4.35	6.25	5.9	3.0	5.1	1.65	0.4	0.05	0.25	0.3	1.25
2	3.6	4.1	5.55	5.35	2.8	4.4	1.55	.35	.05	.25	.3	1.15
3	3.25	4.0	5.05	4.9	2.75	4.1	1.55	.35	.05	.25	.35	1.35
4	3.0	3.75	5.0	4.7	2.65	4.1	1.4	.35	.05	.25	.4	1.2
5	3.15	3.5	4.75	4.45	2.6	3.9	1.3	.35	.05	.25	2.0	1.2
6	3.2	3.35	4.7	4.2	2.5	3.25	1.3	.35	.05	.25	2.1	1.25
7	3.15	3.2	4.6	4.0	2.45	3.25	1.2	.3	.05	.2	2.8	1.6
8	3.1	3.05	4.6	3.75	2.3	3.4	1.2	.25	.05	.2	3.1	4.0
9	4.7	2.95	4.5	3.7	2.25	3.95	1.1	.25	.05	.15	2.8	4.1
10	5.25	2.85	4.35	3.7	2.25	4.1	1.05	.25	.1	.15	2.6	4.4
11	4.5	2.75	4.2	3.45	2.25	4.1	1.05	.2	.15	.15	1.9	5.8
12	6.45	2.6	4.0	3.25	2.2	4.0	1.0	.2	.25	.2	1.65	5.0
13	8.2	2.55	3.75	3.1	2.1	3.8	.95	.2	.45	.3	1.45	4.1
14	6.75	2.5	3.55	2.9	2.1	3.55	.95	.2	.6	.35	1.35	3.5
15	6.6	3.0	3.35	2.9	2.7	3.3	.85	.15	.8	.35	1.1	3.5
16	18.1	3.0	3.2	2.9	3.6	3.3	.8	.15	.9	35	4.35	5.25
17	9.9	3.05	3.05	2.8	3.4	3.3	.8	.15	.9	.45	3.95	4.65
18	7.4	3.65	2.9	2.7	3.15	3.1	.8	.1	.85	1.05	5.3	4.05
19	6.0	6.2	3.0	2.6	2.95	2.85	.75	.1	.75	1.00	4.2	4.0
20	5.35	9.05	3.1	2.55	2.7	2.65	.7	.05	.6	.95	3.6	4.4
21	4.4	10.7	3.5	2.55	2.55	2.5	.65	.05	.4	.75	3.1	4.4
22	4.45	10.3	3.95	2.65	2.75	2.4	.65	.05	.3	.75	3.95	3.9
23	4.65	8.3	4.15	2.75	3.4	2.25	.6	.05	.35	.65	3.6	3.5
24	6.65	8.0	4.0	2.8	3.2	2.15	.6	.05	.4	.65	3.1	3.35
25	6.3	7.3	4.0	2.8	3.0	2.05	.55	.05	.45	.5	2.75	3.6
26	5.8	7.25	4.05	2.8	3.0	1.9	.55	.05	.45	.45	2.3	6.55
27	5.1	8.5	4.05	2.75	3.4	1.9	.5	.05	.3	.45	2.05	5.8
28	4.75	7.3	3.8	3.2	3.7	1.9	.5	.05	.25	.4	1.75	4.85
29	4.4	....	3.6	3.3	9.1	1.85	.45	.05	.25	.4	1.65	4.3
30	4.15	....	3.45	3.15	7.4	1.75	.45	.05	.25	.35	1.4	3.95
31	4.4	....	4.25	....	6.0	....	.4	.05	....	.35	....	4.9

Rating table for South Fork of Umpqua River near Brockway, Oreg., for 1905-6.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet*	*Sec.-ft.*
0.00	160	1.20	544	2.40	1,210	4.20	3,210	9.00	15,600
0.10	182	1.30	585	2.50	1,280	4.40	3,540	10.00	18,760
0.20	206	1.40	627	2.60	1,360	4.60	3,890	11.00	21,980
0.30	232	1.50	670	2.70	1,440	4.80	4,260	12.00	25,280
0.40	260	1.60	715	2.80	1,520	5.00	4,650	13.00	28,600
0.50	290	1.70	765	2.90	1,610	5.20	5,060	14.00	32,000
0.60	321	1.80	820	3.00	1,700	5.40	5,500	15.00	35,400
0.70	354	1.90	880	3.20	1,900	5.60	5,960	16.00	38,900
0.80	389	2.00	940	3.40	2,110	5.80	6,440	17.00	42,400
0.90	426	2.10	1,005	3.60	2,340	6.00	6,940	18.00	46,000
1.00	465	2.20	1,070	3.80	2,610	7.00	9,610		
1.10	504	2.30	1,140	4.00	2,900	8.00	12,530		

NOTE.—The above table is applicable only to open-channel conditions. It is based on 9 discharge measurements made during 1905-6 and is well defined below gage height 9 feet.

Monthly discharge of South Fork of Umpqua River near Brockway, Oreg., for 1905–6.

[Drainage area, 1,800 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft per sq. mile.	Depth in inches.
1905.						
December 6-31	7,190	484	1,480	76,300	0.822	0.795
1906.						
January	46,400	1,700	6,760	416,000	3.76	4.34
February	21,000	1,280	6,120	340,000	3.40	3.54
March	7,580	1,610	3,160	194,000	1.76	2.03
April	6,690	1,320	2,340	139,000	1.30	1.45
May	15,900	1,000	2,480	152,000	1.38	1.59
June	4,850	792	2,020	120,000	1.12	1.25
July	740	260	434	26,700	2.41	.28
August	260	171	200	12,300	.111	.13
September	426	171	250	14,900	.139	.16
October	484	194	272	16,700	.151	.17
November	5,280	232	1,470	87,500	.817	.91
December	8,380	524	3,010	185,000	1.67	1.92
The year	46,400	171	2,380	1,700,000	1.50	17.77

NOTE.—Values for 1905 and 1906 are rated as excellent.

ILLINOIS RIVER DRAINAGE BASIN.

ROGUE RIVER NEAR TOLO, OREG.[a]

This station was established August 30, 1905. It is located at Gold Ray, Oreg., 1½ miles below Tolo post-office, just below the Condor Water and Power Company's dam and bridge, and a short distance below the mouth of Stewart Creek. The conditions at this station and the bench marks are described in Water-Supply Paper No. 177, page 249.

Discharge measurements of Rogue River near Tolo, Oreg., in 1905–6.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
1905.		*Feet.*	*Sq. ft.*	*Feet.*	*Sec.-ft.*
August 30	L. R. Allen	180	1,010	1.10	1,310
October 17	do	180	1,020	1.20	1,210
December 26	do	184	1,100	1.57	1,510
1906.					
January 29	L. R. Allen	188	1,270	2.51	2,920
March 19	do	190	1,230	2.33	2,670
April 30	do	192	1,470	3.24	4,570
May 31	do	200	1,500	3.72	5,360
July 12	do	184	1,100	1.64	1,800
September 12	I. E. Oakes	178	981	1.06	1,350

---

[a] Referred to in 1905 report as "Gold Ray."

Daily gage height, in feet, of Rogue River near Tolo, Oreg., for 1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.5	2.65	3.6	....	3.1	3.8	2.1	1.6	1.05	1.1	1.2	1.45
2	1.38	2.6	3.15	3.7	3.2	3.7	2.5	1.6	1.05	1.1	1.2	1.5
3	1.4	2.55	2.9	3.5	3.1	3.6	2.5	1.5	1.05	1.1	1.3	1.4
4	1.48	2.4	2.85	3.3	3.2	3.6	2.5	1.5	1.1	1.1	1.55	1.4
5	1.45	2.35	2.75	3.3	3.3	3.4	2.6	1.3	1.1	1.1	1.7	1.4
6	1.4	2.3	2.75	3.4	3.2	3.3	2.5	1.3	1.1	1.1	1.75	1.55
7	1.4	2.25	2.9	3.4	3.2	3.3	2.4	1.3	1.1	1.1	2.0	1.7
8	1.5	2.2	2.95	3.3	3.1	3.2	2.4	1.3	1.1	1.1	1.95	2.75
9	1.7	2.18	3.0	3.4	3.2	3.7	2.4	1.2	1.1	1.1	1.8	2.15
10	2.05	2.1	3.0	3.2	3.4	3.5	2.3	1.3	1.1	1.1	1.65	2.1
11	1.9	2.1	3.1	3.0	3.3	3.3	2.4	1.2	1.1	1.1	1.35	2.05
12	2.25	2.05	3.15	3.0	3.1	3.3	2.3	1.2	1.1	1.1	1.3	2.1
13	3.2	2.0	3.0	2.9	2.9	3.2	2.2	1.25	1.2	1.1	1.35	2.2
14	2.78	1.95	3.0	3.0	3.0	3.1	2.2	1.3	1.4	1.1	1.4	2.0
15	2.65	2.3	2.8	2.9	3.2	2.9	2.3	1.2	1.5	1.2	1.45	2.2
16	11.4	2.25	2.7	3.1	2.9	3.0	2.3	1.25	1.45	1.35	2.1	2.7
17	4.4	2.25	2.6	2.9	3.0	2.9	2.2	1.2	1.25	1.5	2.15	2.25
18	4.0	2.82	2.5	2.9	2.8	2.8	2.2	1.2	1.2	1.5	2.05	2.15
19	3.5	4.5	2.4	3.0	2.7	2.8	2.1	1.2	1.2	1.35	1.7	2.2
20	2.8	4.4	2.5	3.2	....	2.75	2.1	1.2	1.2	1.2	1.5	2.45
21	2.4	4.7	2.8	3.4	2.7	2.7	2.2	1.2	1.2	1.2	1.65	2.4
22	2.25	4.5	3.1	....	3.0	2.6	2.1	1.2	1.15	1.2	1.7	2.2
23	3.75	4.4	2.8	3.5	2.9	2.5	2.0	1.2	1.1	1.2	1.55	2.25
24	3.85	4.0	2.7	3.3	2.7	2.4	2.0	1.2	1.1	1.25	1.4	2.4
25	3.7	3.7	3.0	3.4	2.6	2.3	2.0	1.2	1.1	1.3	1.4	3.5
26	3.25	3.8	3.5	3.0	2.7	2.35	1.9	1.2	1.1	1.35	1.35	4.75
27	2.95	4.6	3.1	3.2	....	2.4	1.9	1.2	1.1	1.3	1.4	3.4
28	2.75	3.9	3.0	3.3	3.8	2.3	1.7	1.2	1.1	1.2	1.35	2.95
29	2.55	....	2.8	3.2	4.7	2.3	1.8	1.2	1.1	1.2	1.35	2.95
30	2.5	....	2.9	3.1	4.4	2.2	1.7	1.05	1.1	1.2	1.35	3.15
31	2.7	....	5.1	....	3.9	....	1.7	1.1	....	1.2	....	2.9

Rating table for Rogue River near Tolo, Oreg., for 1905-6.

Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.00	1,200	2.00	2,160	3.00	3,830	4.00	6,000	6.00	11,320
1.10	1,270	2.10	2,300	3.10	4,030	4.20	6,480	6.20	11,900
1.20	1,340	2.20	2,450	3.20	4,230	4.40	6,980	6.40	12,480
1.30	1,420	2.30	2,600	3.30	4,440	4.60	7,490	6.60	13,060
1.40	1,500	2.40	2,760	3.40	4,650	4.80	8,010	6.80	13,660
1.50	1,590	2.50	2,930	3.50	4,870	5.00	8,540	7.00	14,260
1.60	1,690	2.60	3,100	3.60	5,090	5.20	9,080	8.00	17,280
1.70	1,800	2.70	3,280	3.70	5,310	5.40	9,620	9.00	20,500
1.80	1,910	2.80	3,460	3.80	5,540	5.60	10,180	10.00	23,850
1.90	2,030	2.90	3,640	3.90	5,770	5.80	10,740	11.00	27,300

NOTE.—The above table is applicable only for open-channel conditions. It is based on 8 discharge measurements made during 1905-6 and is fairly well defined below gage height 4 feet.

Monthly discharge of Rogue River near Tolo, Oreg., for 1905-1906.

[Drainage area, 2,020 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1905.						
September	1,690	1,240	1,300	77,400	0.644	0.718
October	1,690	1,300	1,390	85,500	.688	.793
November	1,590	1,340	1,370	81,500	.678	.756
December	1,930	1,320	1,490	91,600	.738	.851
The period				336,000		
1906.						
January	27,800	1,480	4,000	246,000	1.98	2.28
February	7,750	2,090	4,040	224,000	2.00	2.08
March	8,810	2,760	3,840	236,000	1.90	2.19
April	7,060	3,640	4,370	260,000	2.16	2.41
May	7,750	3,100	4,220	259,000	2.09	2.41
June	5,540	2,450	3,840	228,000	1.90	2.12
July	3,100	1,800	2,440	150,000	1.21	1.40
August	1,690	1,230	1,390	85,500	.688	.79
September	1,590	1,230	1,310	78,000	.648	.72
October	1,590	1,270	1,340	82,400	.663	.76
November	2,380	1,340	1,680	100,000	.832	.93
December	7,880	1,500	2,820	173,000	1.40	1.61
The year	27,800	1,230	2,940	2,120,000	1.46	19.70

NOTE.—Discharges have been interpolated for days when gage was not read. Values for 1905-1906 are rated good.

ROGUE RIVER NEAR GALICE, OREG.

This station was established May 29, 1906. It is located at the ferry on the Mertin-Galice road in sec., 9, T. 35 S., R. 7 W. The gage is an inclined staff on the left bank.

Gage heights, discharge measurements, and monthly discharges have been furnished by Charles Gilman Hyde, University of California, Berkeley, Cal.

Discharge measurements of Rogue River near Galice, Oreg., in 1906.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
May 16	C. G. Hyde	6.5	4,170
August 6	do	4.5	1,400

Daily gage height of Rogue River at Galice, Oregon, for 1906.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		7.5	5.6	4.5	4.35	4.4	4.35	4.6
2		7.4	5.5	4.5	4.35	4.4	4.4	4.6
3		7.3	5.5	4.5	4.35	4.4	4.5	4.5
4		7.6	5.4	4.5	4.35	4.4	4.6	4.5
5		7.4	5.4	4.5	4.35	4.4	4.85	4.6
6		7.1	5.3	4.5	4.35	4.35	4.75	5.3
7		7.2	5.3	4.5	4.3	4.35	4.65	5.8
8		7.1	5.2	4.5	4.25	4.35	5.8	6.3
9		7.7	5.15	4.5	4.4	4.3	5.0	6.1
10		7.5	5.05	4.4	4.5	4.35	4.8	6.0
11		7.3	5.0	4.4	4.4	4.35	4.8	5.8
12		7.5	5.0	4.4	4.35	4.35	4.8	5.6
13		7.2	4.9	4.4	4.5	4.35	4.75	5.5
14		7.0	4.9	4.4	4.7	4.35	4.75	5.4
15		6.8	4.9	4.4	4.6	4.4	5.0	5.8
16		7.2	4.9	4.4	4.5	4.4	5.85	6.8
17		6.9	4.8	4.4	4.5	4.5	5.85	6.2
18		6.7	4.8	4.4	4.5	4.5	5.8	5.7
19		6.5	4.8	4.4	4.4	4.5	5.5	5.5
20		6.4	4.7	4.4	4.4	4.5	5.0	5.7
21		6.3	4.7	4.4	4.5	4.5	5.0	6.0
22		6.2	4.7	4.4	4.5	4.5	5.2	5.7
23		6.1	4.7	4.4	4.4	4.45	5.0	5.6
24		6.1	4.7	4.4	4.4	4.45	5.0	5.6
25		6.0	4.6	4.4	4.4	4.45	4.9	6.7
26		5.9	4.6	4.4	4.4	4.4	4.9	9.8
27		5.9	4.6	4.4	4.4	4.4	4.8	8.1
28		5.8	4.5	4.4	4.4	4.4	4.7	7.0
29	9.0	5.7	4.5	4.4	4.3	4.35	4.7	6.8
30	8.6	5.6	4.5	4.4	4.3	4.35	4.6	7.5
31	8.5		4.5	4.4		4.35		7.0

Monthly discharge of Rogue River near Galice, Oreg., in 1906.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
June	6,250	2,700	4,700	280,000
July	2,700	1,400	1,800	111,000
August	1,400	1,350	1,360	83,600
September	1,600	1,225	1,350	80,300
October	1,400	1,300	1,350	83,000
November	3,125	1,300	1,850	110,000
December	9,950	1,400	3,350	206,000
The period				954,000

NEHALEM RIVER DRAINAGE BASIN.

NEHALEM RIVER AT FISHHAWK, OREG.

This station is located at Fishhawk post-office, below the mouth of Fishhawk Creek. The bed of the stream is of clean sand, liable to shift. Measurements are made from a cable and car. The gage rod is a 2 by 8 inch timber in four sections. The bench mark is the top of three spikes driven in the upper side of a cedar stump about 50 feet above the cable on the left bank; elevation, 23.69 feet above the datum of the gage. No gage heights were observed during 1906.

Discharge measurements of Nehalem River at Fishhawk, Oreg., in 1906.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
April 18	L. R. Allen	59	316	1.02	386
April 19	do	59	203	.93	364
May 21	do	59	284	.52	310
August 1	do	55	179	.24	102

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements were made in North Pacific Ocean drainage in 1906:

Miscellaneous measurements in North Pacific Ocean drainage in 1906.

Date.	Stream.	Locality.	Width.	Area of section.	Discharge.
			Feet.	*Sq. ft.*	*Sec.-ft.*
August 5	Antelope Creek	Eagle Point			0
August 8	Applegate Creek	Ruch	41	88	110
August 5	Big Butte Creek	Sec. 14, T. 34 S., R. 1 E.	102	291	184
August 6	Condor Water and Power Co.'s canal.	Prospect, 200 feet below dam.	14	36	74
August 7	Elk Creek	Sec. 31, T. 33 S., R. 1 W.	25	20	9.1
August 5	Little Butte Creek	Eagle Point	36	42	48
August 6	Rogue River	Prospect, below dam	53	289	445
August 13	Siuslaw River	Below Walton Creek, sec. 16, T. 18 S., R. 8 W.	107	127	131
August 7	Trail Creek	Mouth			0

INDEX.

A. Page.

- Acknowledgments 16-17
- Acre-foot, definition of 4
- Albany, Oreg.
  - Willamette River at:
    - description 156
    - discharge 157
    - discharge, monthly 158
    - gage heights 157
    - rating tables 157-158
- Allen, L. R., work of 1
- Allen ditch at—
  - Echo, Oreg.:
    - discharge 133
- Antelope Creek at—
  - Eagle Point, Oreg.:
    - discharge 192
- Applegate Creek at—
  - Ruch, Oreg.:
    - discharge 192
- Arlington, Oreg.
  - Willow Creek near:
    - description 134
    - discharge 134
    - discharge, monthly 135
    - gage heights 135
    - rating table 135
- Asotin Creek near—
  - Asotin, Wash.
    - description 118
    - discharge 118, 121
    - discharge, monthly 119
    - gage heights 118
    - rating table 119
- Atanum, Wash.
  - Shaw ditch near:
    - discharge 70
  - Stair ditch near:
    - discharge 70
- Atanum Creek near—
  - Tampico, Wash.:
    - discharge 65

B.

- Baker, Wash.
  - creeks near:
    - discharge 181
- Baker River near—
  - Baker, Wash.:
    - discharge 181
- Barton, Oreg.
  - Clackamas River near:
    - description 174
    - discharge 174
    - discharge, monthly 175

Barton, Oreg.—Continued. Page.

  - Clackamas River near—Continued.
    - gage heights 174-175
    - rating table 175
- Bear Creek near—
  - Wallowa, Oreg.:
    - discharge 121
- Beitle ditch near—
  - Hermiston, Oreg.
    - discharge 133
- Bend, Oreg.
  - Central Oregon canal near:
    - description 146
    - discharge 146
    - discharge, monthly 147
    - gage heights 146
    - rating table 146
  - Deschutes River near:
    - description 141
    - discharge 141
  - Deschutes Irrigation & Power Company's flume at:
    - discharge 154
  - Pilot Butte canal near:
    - description 146
    - discharge 147
    - discharge, monthly 149
    - gage heights 147
    - rating table 148
  - Swalley canal at:
    - discharge 154
  - Tumalo Creek near:
    - description 149-150
    - discharge 150
    - gage heights 150
- Big Butte Creek in—
  - T. 34 S., R. 1 E.:
    - discharge 178
- Big Lost River near
  - Chilly, Idaho:
    - description 87
    - discharge 87
    - discharge, monthly 88
    - gage heights 87
    - rating table 87
  - Mackay, Idaho:
    - description 85
    - discharge 85
    - discharge, monthly 86
    - gage heights 86
    - rating table 86
- Big Wood River near—
  - Shoshone, Idaho:
    - description 88
    - discharge 88

- Big Wood River near—Continued. Page.
  - Shoshone, Idaho Continued.
    - discharge, monthly 89
    - gage heights 88
    - rating table 89
- Biggs, Oreg.
  - Deschutes River near:
    - description 141-142
    - discharge 142
    - discharge, monthly 142
    - gage heights 142
    - rating table 142
- Blackfoot River near
  - Presto, Idaho:
    - description 84
    - discharge 84
    - discharge, monthly 85
    - gage heights 84
    - rating table 85
- Boise River, seepage investigations on 94-97
- Boise River near—
  - Boise, Idaho:
    - discharge 122
  - Highland, Idaho:
    - description 93
    - discharge 93
    - discharge, monthly 94
    - gage heights 93
    - rating table 94
- Bolster, R. H., work of 1
- Boulder Creek near -
  - Detroit, Oreg.:
    - discharge 176
- Breitenbush Creek, mouth of
  - Santiam River near:
    - discharge 177-178
- Breitenbush Creek near -
  - Detroit, Oreg.:
    - discharge 176
- Brockway, Oreg.
  - Umpqua River, South Fork, near:
    - description 186
    - discharge 186
    - discharge, monthly 188
    - gage heights 187
    - rating table 187
- Brownell canal at—
  - Hermiston, Oreg.:
    - discharge 134
- Buffalo River near
  - Elk, Wyo.:
    - description 82
    - discharge 82
    - gage heights 83
- Buffalo River, North Fork, at
  - most northerly meadows, Wyoming:
    - discharge 122
- Bull canal at—
  - Ellensburg, Wash.:
    - discharge 70
- Bull Run Creek near—
  - Portland, Oreg.:
    - discharge 19
- Bully Creek at and above -
  - Vale, Oreg.:
    - description 103, 105
    - discharge 103, 105
- Bully Creek at and above—Continued. Page.
  - Vale, Oreg.—Continued.
    - discharge, monthly 105
    - gage heights 104
    - rating tables 104
- Bumping River near—
  - Nile, Wash.:
    - description 60
    - discharge 60
    - discharge, monthly 61
    - gage heights 60
    - rating table 61
- Burnt River near-
  - Huntington, Oreg.:
    - discharge 122

C.

- Cabin Creek near—
  - Easton, Wash.:
    - discharge 66
- Cable station, figures showing 11, 44
- Calapooia Creek in—
  - T. 12 S., R. 3 W.:
    - discharge 176
- Canada Creek mouth, Wash.
  - Carbon River near:
    - discharge 181
- Canada Creek near—
  - mouth:
    - discharge 181
- Canyon Creek at—
  - Canyon City, Oreg.:
    - discharge 137
- Carbon River at and near—
  - Canada Creek mouth, Wash.:
    - discharge 181
  - Fairfax, Wash.:
    - discharge 181
- Cascade canal near—
  - Thorp, Wash.:
    - discharge 70
- Cashmere, Wash.
  - Wenache River at:
    - description 39
    - discharge 39
    - discharge, monthly 40
    - gage heights 40
    - rating table 40
- Catherine Creek at—
  - Union, Oreg.:
    - description 112
    - discharge 112
    - gage heights 113
- Cedar Creek near—
  - Mackay, Idaho:
    - discharge 122
- Cedar River near—
  - Ravensdale, Wash.:
    - description 179
    - discharge 179
    - discharge, monthly 180
    - gage heights 179-180
    - rating table 180
- Central Oregon canal near—
  - Bend, Oreg.:
    - description 146
    - discharge 146

Central Oregon canal near—Continued. Page.
- Bend, Oreg.—Continued.
  - discharge, monthly.................. 147
  - gage heights.................. 146
  - rating table.................. 146

Chelan River at—
- Chelan, Wash.:
  - description.................. 37-38
  - discharge.................. 38
  - discharge, monthly.................. 39
  - gage heights.................. 38
  - rating table.................. 38

Chelan River basin:
- description.................. 37

Chemuis Creek near—
- Carbon River, Wash.:
  - discharge.................. 181

Chilly, Idaho.
- Big Lost River near:
  - description.................. 87
  - discharge.................. 87
  - discharge, monthly.................. 88
  - gage heights.................. 87
  - rating table.................. 87

Clackamas River near—
- Barton, Oreg.:
  - description.................. 174
  - discharge.................. 174
  - discharge, monthly.................. 175
  - gage heights.................. 174-175
  - rating table.................. 175

Clark Fork at and near—
- Grantsdale, Mont.:
  - description.................. 20
  - discharge.................. 20
  - discharge, monthly.................. 21
  - gage heights.................. 21
  - rating table.................. 21
- Missoula, Mont.:
  - description.................. 22
  - discharge.................. 22
  - discharge, monthly.................. 23
  - gage heights.................. 22
  - rating table.................. 23

Clark Fork basin:
- description.................. 20

Clealum, Wash.
- Yakima River at:
  - description.................. 43
  - discharge.................. 43
  - discharge, monthly.................. 44
  - gage heights.................. 43
  - rating table.................. 43

Clealum Lake, Wash.
- Clealum River near:
  - discharge.................. 66

Clealum River near—
- Clealum Lake, Wash.:
  - discharge.................. 66
- Roslyn, Wash.:
  - description.................. 55
  - discharge.................. 55
  - discharge, monthly.................. 56
  - gage heights.................. 55
  - rating table.................. 56

Columbia Falls, Mont.
- Flathead River at:
  - discharge.................. 30

Columbia River near— Page.
- Pasco, Wash.:
  - description.................. 18
  - gage heights.................. 19

Columbia River basin:
- description.................. 17-18
- miscellaneous measurements.................. 19

Columbia Southern canal near—
- Laidlaw, Oreg.:
  - description.................. 151
  - discharge.................. 151
  - discharge, monthly.................. 152
  - gage heights.................. 151
  - rating table.................. 152

Computation, methods of.................. 13-16

Condor Water and Power Co.'s canal at—
- Prospect, Oreg.:
  - discharge.................. 192

Cooperation, acknowledgment of.................. 16-17

Couse Creek near—
- Milton, Oreg.:
  - discharge.................. 126

Cowiche canal at and near—
- Cowiche, Wash.:
  - discharge.................. 70

Cowiche Creek near—
- Cowiche, Wash.:
  - discharge.................. 66

Crabtree Creek near—
- Thomas, Oreg.:
  - discharge.................. 176

Crescent Creek at—
- Crescent Lake outlet:
  - discharge.................. 154

Crow Creek near—
- Ronan, Mont.:
  - description.................. 25-26
  - discharge.................. 26
  - discharge, monthly.................. 27
  - gage heights.................. 26
  - rating table.................. 26

Cupper, P. A., work of.................. 1

Current meters, classes of.................. 10
- methods of using.................. 10-11
- plate showing.................. 10

Curves (discharge, area, and velocity), figure showing.................. 14

D.

Dalles. *See* The Dalles.

Definitions of terms used.................. 3-4

Dell, Oreg.
- Willow Creek near:
  - description.................. 106
  - discharge.................. 107
  - discharge, monthly.................. 107
  - gage heights.................. 107
  - rating table.................. 107

Deschutes Irrigation and Power Company's flume near—
- Bend, Oreg.:
  - discharge.................. 154

Deschutes River at and near—
- Bend, Oreg.:
  - description.................. 141
  - discharge.................. 141

Deschutes River at and near—Cont'd. Page.
- Biggs, Oreg.:
  - description, 141–142
  - discharge, 142
  - discharge, monthly, 142
  - gage heights, 142
  - rating table, 142
- Lava, Oreg.:
  - description, 138
  - discharge, 138
  - discharge, monthly, 139
  - gage heights, 138–139
  - rating table, 139
- Moro, Oreg.:
  - discharge, 154
- Warm Springs Ferry:
  - discharge, 154
- West's (B. F.) ranch:
  - description, 140
  - discharge, 140
  - discharge, monthly, 141
  - gage heights, 140
  - rating table, 140

Deschutes River basin:
- description, 138

Deschutes River, East Fork at—
- Odell, Oreg.:
  - description, 143
  - discharge, 143
  - discharge, monthly, 144
  - gage heights, 143
  - rating table, 143

Deschutes River, West Fork, near—
- Lava, Oreg.:
  - description, 144
  - discharge, 144
  - discharge, monthly, 145
  - gage heights, 144–145
  - rating tables, 145

Desolation Creek near—
- Roslyn, Wash.:
  - discharge, 66

Detroit, Oreg.
- Boulder Creek near:
  - discharge, 176
- Breitenbush Creek near:
  - discharge, 176

Discharge, measurement and computation of, 13–16

Drainage basins, list of, 2–3

Dry Creek near—
- Milton, Oreg.:
  - discharge, 126

E.

Eagle Point, Oreg.
- Antelope Creek at:
  - discharge, 192
- Little Butte Creek at:
  - discharge, 192

Easton, Wash.
- Cabin Creek near:
  - discharge, 66
- Kachess Lake near:
  - description, 53
  - gage heights, 53

Easton, Wash.—Continued. Page.
- Kachess River near:
  - description, 53
  - discharge, 53
  - discharge, monthly, 54
  - gage heights, 54
  - rating table, 54
- Silver Creek near:
  - discharge, 66
- Yakima River near:
  - discharge, 66

Echo, Oreg.
- Allen ditch at:
  - discharge, 133
- Hinkle ditch at:
  - discharge, 133
- Lisle (Charles) ditch at:
  - discharge, 132
- Maxwell ditch at:
  - discharge, 134
- Mill canal at:
  - discharge, 132
- Pioneer ditch at:
  - discharge, 133
- Wilson & Co.'s ditch at:
  - description, 133

Eightmile Creek at—
- The Dalles, Oreg.:
  - discharge, 19

Elgin, Oreg.
- Wallowa River near:
  - description, 116
  - discharge, 116
  - discharge, monthly, 117
  - gage heights, 117
  - rating table, 117

Elk, Wyo.
- Buffalo River near:
  - description, 82
  - discharge, 82
  - gage heights, 83

Elk Creek in—
- T. 33 S., R. 1 W.:
  - discharge, 192

Elkton, Oreg.
- Umpqua River at:
  - description, 183
  - discharge, 183
  - gage heights, 183
  - rating table, 184

Ellensburg, Wash.
- Bull canal at:
  - discharge, 70
- Olsen canal at:
  - discharge, 70
- Town canal near:
  - discharge, 70

Equivalents, table of, 6–7

F.

Fairfax, Wash.
- Carbon River at:
  - discharge, 181

Fall River at—
- Fremont, Idaho:
  - description, 76
  - discharge, 76

Fall River at—Continued. Page.
  Fremont, Idaho—Continued.
    discharge, monthly 77
    gage heights 77
    rating table 77
Farmers ditch at—
  Tampico, Wash.:
    discharge 70
Fishhawk, Oreg.
  Nehalem River at:
    description 191
    discharge 192
Fivepoint Creek near—
  Hilgard, Oreg.:
    discharge 121
Flathead River (South Fork) at—
  Columbia Falls, Mont.:
    discharge 30
Follansbee, Robert, work of 1
Forest, Oreg.
  Crooked River near:
    discharge 154
Fortune canal at—
  Fosters ranch, Wash.:
    description 70
Foster, Oreg.
  Middle Fork of Santiam River near:
    discharge 177
  South Fork of Santiam River at:
    discharge 178
Foster's ranch, Wash.
  Fortune canal at:
    discharge 70
Fowler canal near—
  North Yakima, Wash.:
    discharge 70
Fremont, Idaho.
  Fall River at:
    description 76
    discharge 76
    discharge, monthly 77
    gage heights 77
    rating table 77

G.

Gaging stations, equipment of 9–10
  location of, map showing 2
Galice, Oreg.
  Rogue River near:
    description 190
    discharge 190
    discharge, monthly 191
    gage heights 191
Gibbon, Oreg.
  Meacham Creek at:
    discharge 131
  Umatilla River near:
    description 126
    discharge 127
    discharge, monthly 127
    gage heights 127
    rating table 127
Goshen, Oreg.
  Coast Fork of Willamette River near:
    description 160
    discharge 161
    discharge, monthly 162

Goshen, Oreg.—Continued. Page.
  Coast Fork of Willamette River near—Continued.
    gage heights 161
    rating table 161
Grande Ronde River near—
  Hilgard, Oreg.:
    description 109
    discharge 110
    discharge, monthly 111
    gage heights 110
    rating table 111
  Zindel, Wash.:
    description 111
    discharge 111
    gage heights 112
Granger canal near—
  North Yakima, Wash.:
    discharge 70
Grantsdale, Mont.
  Clark Fork at and near:
    description 20
    discharge 20
    discharge, monthly 21
    gage heights 21
    rating table 21

H.

Hall, R. M., work of 1
Hatch canal at—
  Toppenish, Wash.:
    discharge 70
Henshaw, F. F., work of 1
Hermiston, Oreg.
  Beitle ditch near:
    discharge 133
  Brownell canal at:
    discharge 134
  Hermiston ditch near:
    discharge 133
  Minnehaha Spring near:
    discharge 131
Highland, Idaho.
  Boise River near:
    description 93
    discharge 93
    discharge, monthly 94
    gage heights 93
    rating table 94
Hilgard, Oreg.
  Fivepoint Creek near:
    discharge 121
  Grande Ronde River at:
    description 109
    discharge 110
    discharge, monthly 111
    gage heights 110
    rating table 111
Hinkle ditch at—
  Echo, Oreg.:
    discharge 133
Homedale, Idaho.
  Succor Creek near:
    description 89
    discharge 90
    discharge monthly 91
    gage heights 90
    rating table 90

Page.

- Hood River at—
  - Winans City, Oreg.:
    - description, 154
    - discharge, 154
    - discharge, monthly, 156
    - gage heights, 155
    - rating table, 155
- Hooper, Wash.
  - Palouse River at:
    - description, 119–120
    - discharge, monthly, 121
    - gage heights, 120
    - rating table, 120
- Horseshoe Bend, Idaho.
  - Payette River near:
    - description, 97
    - discharge, 97
    - discharge, monthly, 98
    - gage heights, 97–98
    - rating table, 98
- Horseshoe Irrigation Company's ditch at—
  - Yoakum, Oreg.:
    - discharge, 132
- Hoyt, J. C., work in charge of, 1
- Hubbard canal at—
  - North Yakima, Wash.:
    - discharge, 70
- Huntington, Oreg.
  - Burnt River near:
    - discharge, 122
- Hydrographic surveys, organization and scope of, 2

I.

- Ice-covered streams, measurement of, 13

J.

- Jasper, Oreg.
  - Middle Fork of Willamette River at:
    - description, 158
    - discharge, 159
    - discharge monthly, 160
    - gage heights, 159
    - rating table, 159
- Jefferson, Oreg.
  - Santiam River at
    - discharge, 177
- Jocko River at —
  - Ravalli, Mont.:
    - description, 29–30
    - discharge, 30
    - gage heights, 30
- John Day River at—
  - junction with South Fork of Snake, Wyoming:
    - discharge, 122
  - McDonald, Oreg.:
    - description, 135–136
    - discharge, 136
    - discharge, monthly, 137
    - gage heights, 136
    - rating table, 137
- Johnson Creek near—
  - Riverside, Wash.:
    - description, 33–34
    - discharge, daily, 34–35
    - discharge, monthly, 35

Page.

- Joseph, Oreg.
  - Wallowa River at:
    - description, 113
    - discharge, 113
    - discharge, monthly, 114
    - gage heights, 114
    - rating table, 114
- Junction City, Oreg.
  - Long Tom Creek near:
    - discharge, 176

K.

- Kachess Lake
  - tributaries of:
    - discharge, 64
- Kalispell, Mont.
  - Stillwater River near:
    - description, 23–24
    - discharge, 24
    - discharge, monthly, 24
    - gage heights, 24
    - rating table, 24
  - Whitefish River near:
    - description, 25
    - discharge, 25
    - gage heights, 25
- Keechelus Lake
  - near Martin, Wash.:
    - description, 52
    - gage heights, 52
  - tributaries of:
    - discharge, 65
- Kiona, Wash.
  - Yakima River near:
    - description, 49
    - discharge, 49
    - discharge, monthly, 49–50
    - gage heights, 50
    - rating table, 50

L.

- La Rue, E. C., work of, 1
- Laidlaw, Oreg.
  - Columbia Southern canal near:
    - description, 151
    - discharge, 151
    - discharge, monthly, 152
    - gage heights, 151
    - rating table, 152
  - Tumalo Creek near:
    - description, 148
    - discharge, 148
    - discharge, monthly, 149
    - gage heights, 149
    - rating table, 149
  - Wymer canal near:
    - description, 150
    - discharge, 150
    - gage heights, 151
- Landes, William, work of, 1
- Lava, Oreg.
  - Deschutes River near:
    - description, 138
    - discharge, 138
    - discharge, monthly, 139
    - gage heights, 138–139
    - rating table, 139

Lava, Oreg.—Continued. Page.
- West Fork of Deschutes River near:
  - description 144
  - discharge 144
  - discharge, monthly 145
  - gage heights 144-145
  - rating tables 145

Lewis, J. H., cooperation of 1, 16

Lisle (Charles) ditch at—
- Echo, Oreg.:
  - discharge 132

Little Butte Creek at—
- Eagle Point, Oreg.:
  - discharge 192

Long Tom Creek near—
- Junction City, Oreg.:
  - discharge 176

Los Angeles, Cal., current-meter rating station at, view of 10

Lovely, Oreg.
- Minam Creek near:
  - discharge 121
- Wallowa River near:
  - discharge 122

Luckiamute River near—
- Suver, Oreg.:
  - description 168
  - discharge 168
  - discharge, monthly 170
  - gage heights 169
  - rating table 169

Lyon, Idaho.
- South Fork of Snake River near:
  - description 81
  - discharge 81
  - discharge, monthly 82
  - gage heights 81
  - rating table 82

M.

McAllister ditch at—
- Sisters, Oreg.:
  - discharge 154

McDonald, Oreg.
- John Day River at:
  - description 135-136
  - discharge 136
  - discharge, monthly 137
  - gage heights 136
  - rating table 137

McGlashan, H. D., work of 1

McKenzie River near—
- Springfield, Oreg.:
  - description 162
  - discharge 162
  - discharge, monthly 164
  - gage heights 163
  - rating table 163

Mackay, Idaho.
- Big Lost River near:
  - description 85
  - discharge 85
  - discharge, monthly 86
  - gage heights 86
  - rating table 86
- Cedar Creek near:
  - discharge 122

Malheur, Oreg. Page.
- Willow Creek near:
  - description 105
  - discharge 105
  - discharge, monthly 106
  - gage heights 106
  - rating table 106

Malheur River at and near—
- McLaughlin Bridge, near Vale, Oreg.:
  - description 99
  - discharge 99
  - discharge, monthly 100
  - gage heights 99
  - rating table 100
- Vale, Oreg.:
  - description 101
  - discharge 101
  - discharge, monthly 102
  - gage heights 101
  - rating tables 102

Mahleur River, Middle Fork, at—
- Riverside, Oreg.:
  - description 102
  - discharge 102
  - gage heights 103

Malott, Wash.
- Salmon Creek near:
  - description 33
  - gage heights 33

Martin, Wash.
- Lake Keechelus near:
  - description 52
  - gage heights 52
- Yakima River near:
  - description 41
  - discharge 41
  - discharge, monthly 42
  - gage heights 42
  - rating table 42

Marys Creek near—
- Philamath, Oreg.:
  - discharge 176

Maxwell ditch at—
- Echo, Oreg.:
  - discharge 134

Meacham Creek at—
- Gibbon, Oreg.:
  - discharge 131

Mehama, Oreg.
- north fork of North Fork of Santiam River near:
  - discharge 177
- North Fork of Santiam River at:
  - description 164
  - discharge 164
  - discharge, monthly 166
  - gage heights 165
  - rating table 165

Methow River near—
- Pateros, Wash.:
  - description 36
  - discharge 36
  - discharge, monthly 37
  - gage heights 36
  - rating table 37

Methow River basin:
- description 36

Page.

Mill canal at—
  Echo, Oreg.:
    discharge ... 132
Milner dam, Wash.
  Snake River near:
    description ... 75
    discharge ... 75
Milton, Oreg.
  Couse Creek near:
    discharge ... 126
  Dry Creek near:
    discharge ... 126
  Walla Walla River at and near:
    description ... 123
    discharge ... 123, 126
    discharge, monthly ... 124
    gage heights ... 123–124
  Walla Walla River, South Fork, near:
    description ... 124–125
    discharge ... 125, 126
    gage heights ... 125
Minam Creek near—
  Lovely, Oreg.:
    discharge ... 121
Miner's inch, definition of ... 4
Minidoka, Idaho.
  Snake River near:
    description ... 73
    discharge ... 73
    discharge, monthly ... 74
    gage heights ... 74
    rating table ... 74
Minnehaha Spring near—
  Hermiston, Oreg.:
    discharge ... 131
Minto Creek in—
  T. 11 S., R. 7 E.:
    discharge ... 176
Mission Creek near—
  St. Ignatius, Mont.:
    description ... 27
    discharge ... 27
    discharge, monthly ... 28
    gage heights ... 27
    rating table ... 28
Missoula, Mont.
  Clarks Fork at:
    description ... 22
    discharge ... 22
    discharge, monthly ... 23
    gage heights ... 22
    rating table ... 23
Mohawk River near—
  Mohawk, Oreg.:
    discharge ... 176
Molalla River near—
  Molalla, Oreg.:
    description ... 170
    discharge ... 170
    discharge, monthly ... 172
    gage heights ... 171
    rating table ... 171
Moran, Wyo.
  Pacific Creek near—
    description ... 83
    discharge ... 83
    gage heights ... 83

Moran, Wyo.—Continued. Page.
  South Fork of Snake River near:
    description ... 79
    discharge ... 79
    discharge, monthly ... 80
    gage heights ... 80
    rating table ... 80
Moro, Oreg.
  Deschutes River at:
    discharge ... 154
Moxee canal near—
  North Yakima, Wash.:
    discharge ... 70
Multiple-point method of measuring discharge, description of ... 11–12
Mud Creek near—
  Ronan, Mont.:
    discharge ... 30
Muldrow, W. C., work of ... 1

N.

Naches River near—
  Nile:
    description ... 56
    discharge ... 57
    discharge, monthly ... 58
    gage heights ... 57
    rating table ... 57
  North Yakima:
    description ... 58
    discharge ... 58
    discharge, monthly ... 60
    gage heights ... 59
    rating tables ... 59
Natchez, Wash.
  Oak Creek near:
    discharge ... 66
  Selah Valley canal at:
    discharge ... 70
  Tieton River at headworks near:
    description ... 61
    discharge ... 61
    gage heights ... 62
  Tieton River near:
    description ... 62
    discharge ... 62
    discharge, monthly ... 64
    gage heights ... 63
    rating tables ... 63–64
Neeley, Idaho.
  Snake River at:
    description ... 76
    gage heights ... 76
Nehalem River at—
  Fishhawk, Oreg.:
    description ... 191
    discharge ... 192
New Reservation canal near—
  Yakima, Wash.:
    description ... 68
    discharge ... 68
    gage heights ... 68
Nile, Wash.
  Bumping River near:
    description ... 60
    discharge ... 60
    discharge, monthly ... 61
    gage heights ... 60
    rating table ... 61

Nile, Wash.—Continued. Page.
- Naches River near:
  - description........ 56
  - discharge........ 57
  - discharge, monthly........ 58
  - gage heights........ 57
  - rating table........ 57

Nolin, Oreg.
- Slusher & Gould canal at:
  - discharge........ 132

North Yakima, Wash.
- Fowler canal near:
  - discharge........ 70
- Granger canal near:
  - discharge........ 70
- Hubbard canal at:
  - discharge........ 70
- Moxee canal near:
  - discharge........ 70
- Naches River near:
  - description........ 58
  - discharge........ 58
  - discharge, monthly........ 60
  - gage heights........ 59
  - rating table........ 59
- Old Union canal at:
  - discharge........ 70
- Union canal near:
  - description........ 70
- Union Gap canal at:
  - discharge........ 70
- Wapaton canal at:
  - description........ 70

Northern Pacific Ocean basin:
- description........ 181

O.

Oak Creek near—
- Natchez, Wash.:
  - discharge........ 66

Oakcreek, Oreg.
- North Fork of Umpqua River near:
  - description........ 184
  - discharge........ 184
  - discharge, monthly........ 186
  - gage heights........ 185
  - rating table........ 185

Oakes, I. E., work of........ 1

Ochoco Creek at—
- Prineville, Oreg.:
  - discharge........ 154

Odell, Oreg.
- East Fork of Deschutes River at:
  - description........ 143
  - discharge........ 143
  - discharge, monthly........ 144
  - gage heights........ 143
  - rating table........ 143

Okanogan River basin:
- description........ 32–33

Old reservation canal near—
- Wapato, Wash.:
  - description........ 68–69
  - discharge........ 69
  - discharge, monthly........ 70
  - gage heights........ 69
  - rating table........ 69

Old Union canal at— Page.
- North Yakima, Wash.:
  - discharge........ 70

Olsen canal at—
- Ellensburg, Wash.:
  - discharge........ 70

Ora, Idaho.
- North Fork of Snake River near:
  - description........ 72
  - discharge........ 72
  - discharge, monthly........ 73
  - gage heights........ 72
  - rating table........ 73

Oregon, cooperation with........ 16–17

Oregon Land and Water Company's ditch at—
- Umatilla, Oreg.:
  - discharge........ 133

Owyhee River, Oreg.
- near Owyhee:
  - description........ 91
  - discharge........ 91
  - discharge, monthly........ 92
  - gage heights........ 91–92
  - rating table........ 92

P.

Pacific Creek near—
- Moran, Wyo.:
  - description........ 83
  - discharge........ 83
  - gage heights........ 83

Padgett, H. D., work of........ 1

Palouse River near—
- Hooper, Wash.:
  - description........ 119–120
  - discharge, monthly........ 121
  - gage heights........ 120
  - rating table........ 120

Pasco, Wash.
- Columbia River near:
  - description........ 18
  - gage heights........ 19

Pateros, Wash.
- Methow River near:
  - description........ 36
  - discharge........ 36
  - discharge, monthly........ 37
  - gage heights........ 36
  - rating table........ 37

Payette River near—
- Horseshoe Bend, Idaho:
  - description........ 97
  - discharge........ 97
  - discharge, monthly........ 98
  - gage heights........ 97–98
  - rating table........ 98

Pendleton, Oreg.
- Umatilla River near:
  - description........ 132
- Wild Horse Creek near:
  - discharge........ 131

Permelia Creek in—
- T. 10 S., R. 7 E.:
  - discharge........ 176

Philamath, Oreg.
- Marys Creek near—
  - discharge........ 176

Page.

- Pilot Butte Canal near—
  - Bend, Oreg.:
    - description 146
    - discharge 147
    - discharge, monthly 149
    - gage heights 147
    - rating table 148
- Pioneer ditch at—
  - Echo, Oreg.:
    - discharge 133
- Pole Creek at—
  - Sisters, Oreg.:
    - discharge 154
- Post Creek near—
  - St. Ignatius, Mont.:
    - description 28
    - discharge 28
    - discharge, monthly 29
    - gage heights 29
    - rating table 29
- Powder River at—
  - Salisbury, Oreg.:
    - description 108
    - discharge 108
    - discharge, monthly 109
    - gage heights 108
    - rating tables 109
- Presto, Idaho,
  - Blackfoot River near:
    - description 84
    - discharge 84
    - discharge, monthly 85
    - gage heights 84
    - rating table 85
- Price current meter, views of 10
- Prineville, Oreg.
  - Ochoco Creek at:
    - discharge 154
- Prospect, Oreg.
  - Condor Water and Power Co.'s canal:
    - discharge 192
  - Rogue River at:
    - discharge 192
- Prosser, Wash.
  - Prosser canal at:
    - discharge 70
  - Yakima River near:
    - description 47
    - discharge 47
    - discharge, monthly 48
    - gage heights 48
    - rating table 48
- Prosser canal at—
  - Prosser, Wash.:
    - discharge 70
- Puget Sound basin—
  - description 178

R.

- Rating tables, construction of 13-15
- Ravalli, Mont.
  - Jocko River near:
    - description 29-30
    - discharge 30
    - gage heights 30

Page.

- Ravensdale, Wash.
  - Cedar River near:
    - description 179
    - discharge 179
    - discharge, monthly 180
    - gage heights 179-180
    - rating table 180
- Richland, Wash.
  - Yakima River near:
    - description 51, 66-67
    - discharge 51
    - discharge, monthly 52
    - gage heights 51
    - rating table 51
- Riverside, Wash.
  - Johnson Creek near:
    - description 33-34
    - discharge, daily 34-35
    - discharge, monthly 35
  - Middle Fork of Malheur River at:
    - description 102
    - discharge 102
    - Gage heights 103
- Roaring Creek in—
  - T. 11 S., R. 7 E.:
    - discharge 177
- Rock Creek at—
  - Rockcreek, Oreg.:
    - discharge 137
- Rogue River at and near—
  - Galice, Oreg.:
    - description 190
    - discharge 190
    - discharge, monthly 191
    - gage heights 191
  - Prospect, Oreg.:
    - discharge 192
  - Tolo, Oreg.:
    - description 188
    - discharge 188
    - discharge, monthly 190
    - gage heights 189
    - rating table 189
- Ronan, Mont.
  - Crow Creek near:
    - description 25-26
    - discharge 26
    - discharge, monthly 27
    - gage heights 26
    - rating table 26
  - Mud Creek near:
    - discharge 30
- Roslyn, Wash.
  - Clealum River near:
    - description 55
    - discharge 55
    - discharge, monthly 56
    - gage heights 55
    - rating table 56
  - Desolation Creek near:
    - discharge 66
- Ruch, Oreg.
  - Applegate Creek at:
    - discharge 192
- Run-off, computation of 13-16
- Run-off in inches, definition of 4

S. Page.

- St. Anthony, Idaho.
  - Teton River near:
    - description 78
    - discharge 78
    - discharge, monthly 79
    - gage heights 78
    - rating table 79
- St. Ignatius, Mont.
  - Mission Creek near:
    - description 27
    - discharge 27
    - discharge, monthly 28
    - gage heights 27
    - rating table 28
  - Post Creek near:
    - description 28
    - discharge 28
    - discharge, monthly 29
    - gage heights 29
    - rating table 29
- Salisbury, Oreg.
  - Powder River at:
    - description 108
    - discharge 108
    - discharge, monthly 109
    - gage heights 108
    - rating table 109
- Salmon Creek near:
  - Malott, Wash.:
    - description 33
    - gage heights 33
- Salmon River post-office, Oreg.
  - Salmon River at:
    - discharge 19
  - Sandy River near:
    - discharge 19
- Sandy River at and near—
  - Salmon River post-office, Oreg.:
    - discharge 19
  - Troutman, Oreg.:
    - discharge 19
- Santiam River at—
  - Jefferson, Oreg.:
    - discharge 177
- Santiam River, Marion Fork, in—
  - T. 11 S., R. 7 E.:
    - discharge 177
- Santiam River, Middle Fork, near—
  - Foster, Oreg.:
    - discharge 177
- Santiam River, North Fork, in, at, and near—
  - Breitenbush Creek mouth:
    - discharge 177-178
  - Mehama, Oreg.:
    - description 164
    - discharge 164
    - discharge, monthly 166
    - gage heights 165
    - rating table 165
  - T. 10 S., R. 5 E.:
    - discharge 177
  - T. 11 S., R. 7 E.:
    - discharge 178
- Santiam River, north fork of North Fork, near—
  - Mehama, Oreg.:
    - discharge 177
- Santiam River, South Fork, at and in— Page.
  - Foster, Oreg.:
    - discharge 178
  - T. 11 S., R. 2 W.:
    - discharge 178
  - Waterloo, Oreg.:
    - description 166
    - discharge 166
    - discharge, monthly 168
    - gage heights 167
    - rating table 167
  - Withcombe Place, Oreg.:
    - discharge 178
- Santiam River, Thomas Fork, at—
  - Scio, Oreg.:
    - discharge 178
- Scio, Oreg.
  - Thomas Fork of Santiam River at:
    - discharge 178
- Second-feet per square mile, definition of 4
- Second-foot, definition of 4
- Selah Valley canal at
  - Natchez, Wash.:
    - description 70
- Shaw ditch near—
  - Atanum, Wash.:
    - discharge 70
- Sheridan, Oreg.
  - South Fork of Yamhill River at:
    - description 172
    - discharge 173
    - discharge, monthly 174
    - gage heights 173
    - rating table 173
- Shoshone, Idaho.
  - Big Wood River near:
    - description 88
    - discharge 88
    - discharge, monthly 89
    - gage heights 88
    - rating table 89
- Shoshone Falls, Wash.
  - Snake River near:
    - description 75
    - discharge 75
- Siletz River at—
  - Siletz, Oreg.:
    - description 182
    - discharge 182
    - discharge, monthly 183
    - gage heights 182
    - rating table 183
- Silver Creek near—
  - Easton, Wash.:
    - discharge 66
- Single-point method of measuring discharge, description of 12
- Sisters, Oreg.
  - McAllister ditch at:
    - discharge 154
  - Pole Creek at:
    - discharge 154
  - Squaw Creek near:
    - description 152
    - discharge 152
    - discharge, monthly 153
    - gage heights 153
    - rating table 153

Siuslaw River near— Page.
- Walton Creek mouth, Oreg.:
  - discharge ... 192

Slope method of measuring discharge, use and value of ... 7-8

Slusher & Gould canal at
- Nolin, Oreg.:
  - discharge ... 132

Snake River at, between, and near—
- Milner dam and Shoshone Falls, Wash.:
  - description ... 75
  - discharge ... 75
- Minidoka:
  - description ... 73
  - discharge ... 73
  - discharge, monthly ... 74
  - gage heights ... 74
  - rating table ... 74
- Neeley, Idaho:
  - description ... 76
  - gage heights ... 76

Snake River basin:
- description ... 71-72

Snake River, North Fork, near—
- Ora, Idaho:
  - description ... 72
  - discharge ... 72
  - discharge, monthly ... 73
  - gage heights ... 72
  - rating table ... 73

Snake River, South Fork, near—
- Lyon, Idaho:
  - description ... 81
  - discharge ... 81
  - discharge, monthly ... 82
  - gage heights ... 81
  - rating table ... 82
- Moran, Wyo.:
  - description ... 79
  - discharge ... 79
  - discharge, monthly ... 80
  - gage heights ... 80
  - rating table ... 80

Snoqualmie River near—
- Snoqualmie Falls, Wash.:
  - description ... 178
  - gage heights ... 179

Spokane Bridge, Wash.
- Spokane River at:
  - discharge ... 32

Spokane River at—
- Spokane, Wash.:
  - description ... 31
  - discharge ... 31
  - discharge, monthly ... 32
  - gage heights ... 31
  - rating table ... 32
- Spokane Bridge:
  - discharge ... 32

Spokane River basin:
- description ... 30-31

Springfield, Oreg.
- McKenzie River near:
  - description ... 162
  - discharge ... 162

Springfield, Oreg.—Continued. Page.
- McKenzie River near—Continued.
  - discharge, monthly ... 164
  - gage heights ... 163
  - rating table ... 163

Squaw Creek near—
- Sisters, Oreg.:
  - description ... 152
  - discharge ... 152
  - discharge, monthly ... 153
  - gage heights ... 153
  - rating table ... 153

Stair ditch near—
- Atanum, Wash.:
  - discharge ... 70

Stevens, J. C., work in charge of ... 1

Stewart, J. E., work of ... 1

Still River in—
- T. 3 S., R. 7 E.:
  - discharge ... 19

Stillwater River near—
- Kalispell, Mont.:
  - description ... 23-24
  - discharge ... 24
  - discharge, monthly ... 24
  - gage heights ... 24
  - rating table ... 24

Stream flow, measurement and computation of ... 7-13
- papers on, list of ... 3

Succor Creek near—
- Homedale, Idaho:
  - description ... 89
  - discharge ... 90
  - discharge, monthly ... 91
  - gage heights ... 90
  - rating table ... 90

Sunnyside, Wash.
- Yakima River near:
  - discharge ... 66

Sunnyside canal near—
- Yakima, Wash.:
  - description ... 67
  - discharge ... 67
  - discharge, monthly ... 68
  - gage heights ... 67
  - rating table ... 67

Surface water supply, papers on, list of ... 2-3

Suver, Oreg.
- Luckiamute River near:
  - description ... 168
  - discharge ... 168
  - discharge, monthly ... 170
  - gage heights ... 169
  - rating table ... 169

Swalley canal at—
- Bend, Oreg.:
  - discharge ... 154

T.

Tables, explanation of ... 4-6

Tampico, Wash.
- Atanum Creek near:
  - discharge ... 65
- Farmers ditch at:
  - discharge ... 70

Page.
- Taneum canal at—
  - Thorp, Wash.:
    - discharge 70
- Taneum Creek near—
  - Thorp, Wash.:
    - discharge 66
- Teton River near—
  - St. Anthony, Idaho:
    - description 78
    - discharge 78
    - discharge, monthly 79
    - gage heights 78
    - rating table 79
- The Dalles, Oreg.
  - Eightmile Creek at:
    - discharge 19
- Thomas, Oreg.
  - Crabtree Creek near:
    - discharge 176
- Thorp, Wash.
  - Cascade canal near:
    - discharge 70
  - Taneum canal at:
    - discharge 70
  - Taneum Creek near:
    - discharge 66
- Tieton River at and near–
  - headworks near Natchez, Wash.:
    - description 61
    - discharge 61
    - gage heights 62
  - Natchez, Wash.:
    - description 62
    - discharge 62
    - discharge, monthly 64
    - gage heights 63
    - rating tables 63-64
- Tolo, Oreg.
  - Rogue River near:
    - description 188
    - discharge 188
    - discharge, monthly 190
    - gage heights 189
    - rating table 189
- Toppenish, Wash.
  - Hatch canal at:
    - discharge 70
- Town canal near—
  - Ellensburg, Wash.:
    - discharge 70
  - North Yakima, Wash.:
    - description 70
- Trail Creek at—
  - Mouth:
    - discharge 192
- Troutman, Oreg.
  - Sandy River at and near:
    - discharge 19
- Tumalo Creek near–
  - Bend, Oreg.:
    - description 149-150
    - discharge 150
    - gage heights 150
  - Laidlaw, Oreg.:
    - description 148
    - discharge 148

Page.
- Tumalo Creek near—Continued
  - Laidlaw, Oreg.—Continued.
    - discharge, monthly 149
    - gage heights 149
    - rating table 149
- Tygh Valley, Oreg.:
  - White River at
    - discharge 154

U.

- Umatilla, Oreg.
  - Oregon Land and Water Company's ditch at:
    - discharge 133
- Umatilla River near—
  - Fosters, Oreg.:
    - discharge 131
  - Gibbon, Oreg.:
    - description 126
    - discharge 127
    - discharge, monthly 127
    - gage heights 127
    - rating table 127
  - Pendleton, Oreg.:
    - description 132
  - Umatilla, Oreg.:
    - description 129
    - discharge 129
    - discharge, monthly 130
    - gage heights 129
    - rating table 129
  - Yoakum, Oreg.:
    - description 128
    - discharge 128
    - discharge, monthly 129
    - gage heights 128
    - rating table 129
  - Umatilla River basin:
    - description 126
- Umatilla River Valley, canals in 132-134
- Umpqua River at
  - Elkton, Oreg.:
    - description 183
    - discharge 183
    - gage heights 183
    - rating table 184
- Umpqua River, North Fork, near-
  - Oak Creek, Oreg.:
    - description 184
    - discharge 184
    - discharge, monthly 186
    - gage heights 185
    - rating table 185
- Umpqua River, South Fork, near
  - Brockway, Oreg.:
    - description 186
    - discharge 186
    - discharge, monthly 188
    - gage heights 187
    - rating table 187
- Umtanum, Wash.
  - Yakima River at:
    - description 44
    - discharge 44
    - gage heights 44

Page.

- Union, Oreg.
  - Catherine Creek at:
    - description, 112
    - discharge, 112
    - gage heights, 113
- Union canal at—
  - North Yakima, Wash.:
    - description, 70
- Union Gap, Wash., cable station at, view of, 44
- Union Gap, canal at—
  - North Yakima, Wash.:
    - discharge, 70

V.

- Vale, Oreg.
  - Bully Creek at and above:
    - description, 103, 105
    - discharge, 103, 105
    - discharge, monthly, 105
    - gage heights, 104
    - rating tables, 104
  - Malheur River at McLaughlin Bridge near:
    - description, 99
    - discharge, 99
    - discharge, monthly, 100
    - gage heights, 99
    - rating table, 100
  - Malheur River near:
    - description, 101
    - discharge, 101
    - discharge, monthly, 102
    - gage heights, 101
    - rating table, 102
- Velocity methods of measuring discharge, description of, 9–13
- Vertical-integration method of measuring discharge, description of, 12

W.

- Wading, discharge measurement by, view of, 44
- Walla Walla River at and near—
  - Milton, Oreg.:
    - description, 123
    - discharge, 123, 126
    - discharge, monthly, 124
    - gage heights, 123–124
    - rating table, 124
- Walla Walla River, South Fork, near—
  - Milton, Oreg.:
    - description, 124–125
    - discharge, 125, 126
    - gage heights, 125
- Walla Walla River basin:
  - description, 122
- Wallowa, Oreg.
  - Bear Creek near:
    - discharge, 121
- Wallowa River near—
  - Elgin, Oreg.:
    - description, 116
    - discharge, 116
    - discharge, monthly, 117
    - gage heights, 117
    - rating table, 117

Wallowa River near—Continued. Page.

  - Joseph, Oreg.:
    - description, 113
    - discharge, 113
    - discharge, monthly, 114
    - gage heights, 114
    - rating table, 114
  - Lovely, Oreg.:
    - discharge, 122
  - Wallowa, Oreg.:
    - description, 115
    - discharge, 115
    - discharge, monthly, 116
    - gage heights, 115
    - rating tables, 116
- Walton Creek, mouth, Oreg.
  - Siuslaw Creek near:
    - discharge, 192
- Wapato, Wash.
  - Old Reservation canal near:
    - description, 68–69
    - discharge, 69
    - discharge, monthly, 70
    - gage heights, 69
    - rating table, 69
- Wapato canal near—
  - North Yakima, Wash.:
    - description, 70
- Warm Springs Agency, Oreg.
  - Warm Springs at:
    - discharge, 154
- Warm Springs Ferry, Oreg.
  - Deschutes River at:
    - discharge, 154
- Water supply, surface, papers on, list of, 2–3
- Waterloo, Oreg.
  - South Fork of Santiam River at:
    - description, 166
    - discharge, 166
    - discharge, monthly, 168
    - gage heights, 167
    - rating table, 167
- Weir method of measuring discharge requirements of, 8–9
- Wenache River at—
  - Cashmere, Wash.:
    - description, 39
    - discharge, 39
    - discharge, monthly, 40
    - gage heights, 40
    - rating table, 40
- White River at—
  - Tygh Valley, Oreg.:
    - discharge, 154
- White River basin:
  - description, 179
- Whitefish River near—
  - Kalispell, Mont.:
    - description, 25
    - discharge, 25
    - gage heights, 25
- White Water Creek in—
  - T. 10 S., R. 7 E.:
    - discharge, 178
- Wild Horse Creek near—
  - Pendleton, Oreg.:
    - discharge, 131

Page.

- Willamette River at—
  - Albany, Oreg.:
    - description ... 156
    - discharge ... 157
    - discharge, monthly ... 158
    - gage heights ... 157
    - rating tables ... 157-158
- Willamette River, Coast Fork, near—
  - Goshen, Oreg.:
    - description ... 160
    - discharge ... 160
    - discharge, monthly ... 162
    - gage heights ... 161
    - rating table ... 161
- Willamette River, Middle Fork, at—
  - Jasper, Oreg.:
    - description ... 158
    - discharge ... 159
    - discharge, monthly ... 166
    - gage heights ... 159
    - rating table ... 159
- Willamette River basin:
  - description ... 156
- Willow Creek basin:
  - description ... 134
- Willow Creek (of the Columbia) near—
  - Arlington, Oreg.:
    - description ... 134
    - discharge ... 134
    - discharge, monthly ... 135
    - gage heights ... 135
    - rating table ... 135
- Willow Creek (of the Malheur) near—
  - Dell, Oreg.:
    - description ... 106
    - discharge ... 107
    - discharge, monthly ... 107
    - gage heights ... 107
    - rating table ... 107
  - Malheur, Oreg.:
    - description ... 105
    - discharge ... 105
    - discharge, monthly ... 106
    - gage heights ... 106
    - rating table ... 106
- Wilson & Co.'s ditch at—
  - Echo, Oreg.:
    - discharge ... 133
- Winans, Oreg.,
  - Hood River at:
    - description ... 154
    - discharge ... 155
    - discharge, monthly ... 156
    - gage heights ... 155
    - rating table ... 155
- Withcombe Place, Oreg.
  - South Fork of Santiam River at:
    - discharge ... 178
- Wymer canal near—
  - Laidlaw, Oreg.:
    - description ... 150
    - discharge ... 150
    - gage heights ... 151

Y. Page.

- Yakima, Wash.
  - New Reservation canal near:
    - description ... 68
    - discharge ... 68
    - gage heights ... 68
  - Sunnyside canal near:
    - descripton ... 67
    - discharge ... 67
    - discharge, monthly ... 68
    - gage heights ... 67
    - rating table ... 67
- Yakima River, cable station on, view of ... 44
- Yakima River at and near—
  - Clealum, Wash.:
    - description ... 43
    - discharge ... 43
    - discharge, monthly ... 44
    - gage heights ... 43
    - rating table ... 43
  - Easton, Wash.:
    - discharge ... 66
  - Kiona:
    - description ... 49
    - discharge ... 49
    - discharge, monthly ... 50
    - gage heights ... 49-50
    - rating table ... 50
  - Martin:
    - description ... 41
    - discharge ... 41
    - discharge, monthly ... 42
    - gage heights ... 42
    - rating table ... 42
  - Prosser:
    - description ... 47
    - discharge ... 47
    - discharge, monthly ... 48
    - gage heights ... 48
    - rating table ... 48
  - Richland, Wash.:
    - description ... 51
    - discharge ... 51, 66-67
    - discharge, monthly ... 52
    - gage heights ... 51
    - rating table ... 51
  - Sunnyside, Wash.:
    - discharge ... 66
  - Umtanum, Wash:
    - description ... 44
    - discharge ... 44
    - gage heights ... 44
  - Yakima:
    - description ... 45
    - discharge ... 45
    - discharge, monthly ... 46
    - gage heights ... 45
    - rating tables ... 46
- Yakima River Basin:
  - description ... 41
- Yakima Valley, canals in, data on ... 67-70
- Yakima Valley canal near—
  - head:
    - description ... 70

Yamhill River, South Fork, at— Page.
  Sheridan, Oreg.:
    description.......................... 172
    discharge............................ 173
    discharge, monthly................... 174
    gage heights......................... 173
    rating table......................... 173
Yoakum, Oreg.
  Horseshoe Irrigation Company's canal at:
    discharge............................ 132
  Umatilla River near:
    description.......................... 128
    discharge............................ 128
    discharge, monthly................... 129
Yoakum, Oreg.—Continued. Page.
  Umatilla River near—Continued.
    gage heights......................... 128
    rating table......................... 129

Z.

Zigzag Creek in—
  T. 3 S., R. 7 E.:
    discharge............................ 19
Zindel, Wash.
  Grande Ronde River at:
    description.......................... 111
    discharge............................ 111
    gage heights......................... 112

CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 214.]

The publications of the United States Geological Survey consist of (1) Annual Reports; (2) Monographs; (3) Professional Papers; (4) Bulletins; (5) Mineral Resources; (6) Water-Supply and Irrigation Papers; (7) Topographic Atlas of United States, folios and separate sheets thereof; (8) Geologic Atlas of United States, folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists can be had on application.

Most of the above publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained, free of charge (except classes 2, 7, and 8), on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at practically cost.

4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they can be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports; Q, Fuels; R, Structural materials.

Series P.—The hydrographic progress reports contain the results of stream measurements. A report is issued for every calendar year, containing the results of data collected during that year. These reports were first published as a part of the Director's annual report or as a bulletin; they are now published as water-supply and irrigation papers. The following is a list, by years, of the publications containing the progress reports of stream measurements (* means out of stock). A detailed index of these reports (1888–1903) is published as Water-Supply Paper No. 119.

1888. Tenth Annual Report, Part II*.
1889. Eleventh Annual Report, Part II*.
1890. Twelfth Annual Report, Part II*.
1891. Thirteenth Annual Report, Part III*.
1892. Fourteenth Annual Report, Part II*.
1893. Bulletin No. 131*.
1894. Bulletin No. 131*; Sixteenth Annual Report, Part II*.
1895. Bulletin No. 140*.
1896. Water-Supply Paper No. 11*; Eighteenth Annual Report, Part IV*.
1897. Water-Supply Papers Nos. 15* and 16*; Nineteenth Annual Report, Part IV*.
1898. Water-Supply Papers Nos. 27* and 28*; Twentieth Annual Report, Part IV*.
1899. Water-Supply Papers Nos. 35*, 36*, 37*, 38*, and 39*, Twenty-first Annual Report, Part IV*.
1900. Water-Supply Papers Nos. 47, 48, 49, 50, 51, and 52; Twenty-second Annual Report, Part IV.
1901. East of Mississippi River, Water-Supply Papers Nos. 65* and 75*.
West of Mississippi River, Water-Supply Papers Nos. 66 and 75*.

1902. East of Mississippi River, Water-Supply Papers Nos. 82 and 83.
West of Mississippi River, Water-Supply Papers Nos. 84 and 85.
1903. East of Mississippi River, Water-Supply Papers Nos. 97 and 98.
West of Mississippi River, Water-Supply Papers Nos. 99 and 100.
1904. East of Mississippi River, Water-Supply Papers Nos. 124, 125, 126, 127, 128, and 129.
West of Mississippi River, Water-Supply Papers Nos. 130, 131, 132, 133, 134, and 135.
1905. East of Mississippi River, Water-Supply Papers Nos. 165*, 166*, 167, 168*, 169, 170, and 171.
West of Mississippi River, Water-Supply Papers Nos. 171, 172*, 173*, 174, 175*, 176, 177, and 178.
1906. East of Mississippi River, Water-Supply Papers Nos. 201, 202, 203, 204, 205, 206, and 207
West of Mississippi River, Water-Supply Papers Nos. 207, 208, 209, 210, 211, 212, 213, and 214.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

OCTOBER, 1907.

Water-Supply Paper No. 215

Series
A, Economic Geology, 96
B, Descriptive Geology, 118
M, General Hydrographic Investigations, 25
O, Underground Waters, 71

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

GEOLOGY AND WATER RESOURCES

OF A PORTION OF THE

MISSOURI RIVER VALLEY IN NORTHEASTERN NEBRASKA

BY

G. E. CONDRA

WASHINGTON
GOVERNMENT PRINTING OFFICE
1908

CONTENTS.

Page.
- Introduction 5
- Topography 6
- Descriptive geology 6
  - Stratigraphy 6
  - Structure 8
  - Description of the rocks 8
    - Cretaceous system 8
      - Dakota sandstone 8
      - Benton group 10
        - Graneros shale 11
        - Greenhorn limestone 11
        - Carlile shale 12
      - Niobrara formation 13
      - Pierre shale 15
    - Tertiary system 18
      - Arikaree formation 18
      - Pliocene deposits 19
    - Quaternary system 20
      - Glacial drift 20
      - Loess 20
      - Alluvium 21
      - Dune sand 22
- Economic geology 22
  - Mineral resources 22
    - Brick clay 22
    - Sand and gravel 22
    - Building stone 22
    - Cement rock 23
    - Coal 24
    - Peat 24
    - Volcanic ash 24
  - Water resources 25
    - General statement 25
    - Surface waters 25
      - Streams 25
      - Springs 26
    - Underground waters 27
      - Shallow wells 27
      - Artesian wells 28
        - Artesian conditions 28
        - Chemical composition of artesian water 28
        - Pressure 29
        - Temperature of artesian water 30
        - Construction and care of wells 30
        - Diminution in pressure and supply 31

Economic geology—Continued. Page.
- Water resources—Continued.
  - Underground waters—Continued.
    - Blowing wells 31
    - Pollution of well waters 32
  - Water resources, by counties 32
    - Northern part of Holt County 32
    - Boyd County 35
    - Knox County 39
    - Cedar County 45
    - Dixon County 50
    - Dakota County 54
- Agricultural resources 55
  - Soils 55
  - Crops 55
  - Stock raising and dairying 55
- Timber 56

Index 57

ILLUSTRATIONS.

		Page.
Plate I.	Sketch map of Nebraska	6
II.	Geologic map of northeastern Nebraska	In pocket.
III.	Sections across northeastern Nebraska and adjacent regions	In pocket.
IV.	*A*, Dakota sandstone on bank of Missouri River below mouth of Aowa Creek; *B*, Greenhorn limestone on Graneros shale northeast of Ponca, Nebr	10
V.	*A*, Carlile clay overlain by Niobrara, northeast of James, Nebr.; *B*, Calcareous concretions in Carlile formation, west of Vermilion Ferry, Nebr	12
VI.	Characteristic fossils of Niobrara formation and Greenhorn limestone	14
VII.	*A*, One of the Twin Buttes, Boyd County, Nebr.; *B*, Knollkemper dam, Turner, Holt County, Nebr	18
VIII.	*A*, Cement plant near Yankton, S. Dak.; *B*, Niobrara formation, just west of Niobrara, Nebr	24
IX.	Map of northeastern Nebraska region, showing underground water conditions	In pocket.
X.	Second artesian well at Lynch, Nebr	38
XI.	*A*, Old well at Santee Agency, Nebr.; *B*, Lower dam on Bazile Creek, Knox County, Nebr	40

GEOLOGY AND WATER RESOURCES OF A PORTION OF THE MISSOURI RIVER VALLEY IN NORTHEASTERN NEBRASKA.

By G. E. Condra.

INTRODUCTION.

The region considered in this report lies in northeastern Nebraska, south of Missouri River, and extends about 150 miles east and west and approximately 29 miles north and south. The total area is over 4,100 square miles, comprising Dakota, Cedar, Knox, and Boyd counties and the northern part of Holt County, as shown in Pl. I.

The eastern part of the area was settled long ago, and the western counties are now rapidly filling up. The entire region has a fertile soil, and there is sufficient rainfall to insure crops in most seasons, especially where careful cultivation is practiced. Very little irrigation is needed, and a few short ditches constructed during exceptionally dry years are not used at present. In 1903 no irrigation whatever was employed.

Stock raising is carried on extensively where the land is not farmed. There is an abundance of ground water throughout most of the area, yet at places in Boyd, Knox, and Holt counties there is difficulty in obtaining a sufficient supply of good well water for stock and domestic purposes. On this account considerable space is given in this report to ground water and shallow wells in those counties.

Many springs, some of them of good volume, are found in every county. Artesian wells are obtained on the Missouri bottom and adjacent lowlands from eastern Boyd to the northeastern part of Dixon County.

This report is a result of studies made in the field during the summer of 1903, under the direction of N. H. Darton. There was found to be much local interest in cement rock, coal, and the water conditions. Special trips were made into Dixon and Dakota counties with Prof. J. E. Todd, who has furnished important suggestions as to the geology and has supplied several sections. It was found necessary to determine the broader structural and stratigraphic relations of the Cretaceous formations, and, in order to do this, observations were continued into Iowa and South Dakota.

Only about 250 square miles of the area have been topographically surveyed and these are included in the Elk Point quadrangle, which extends from South Dakota into Dixon and Dakota counties. Outside of that area altitudes were obtained from railroad levels and by the use of an aneroid barometer.

TOPOGRAPHY.

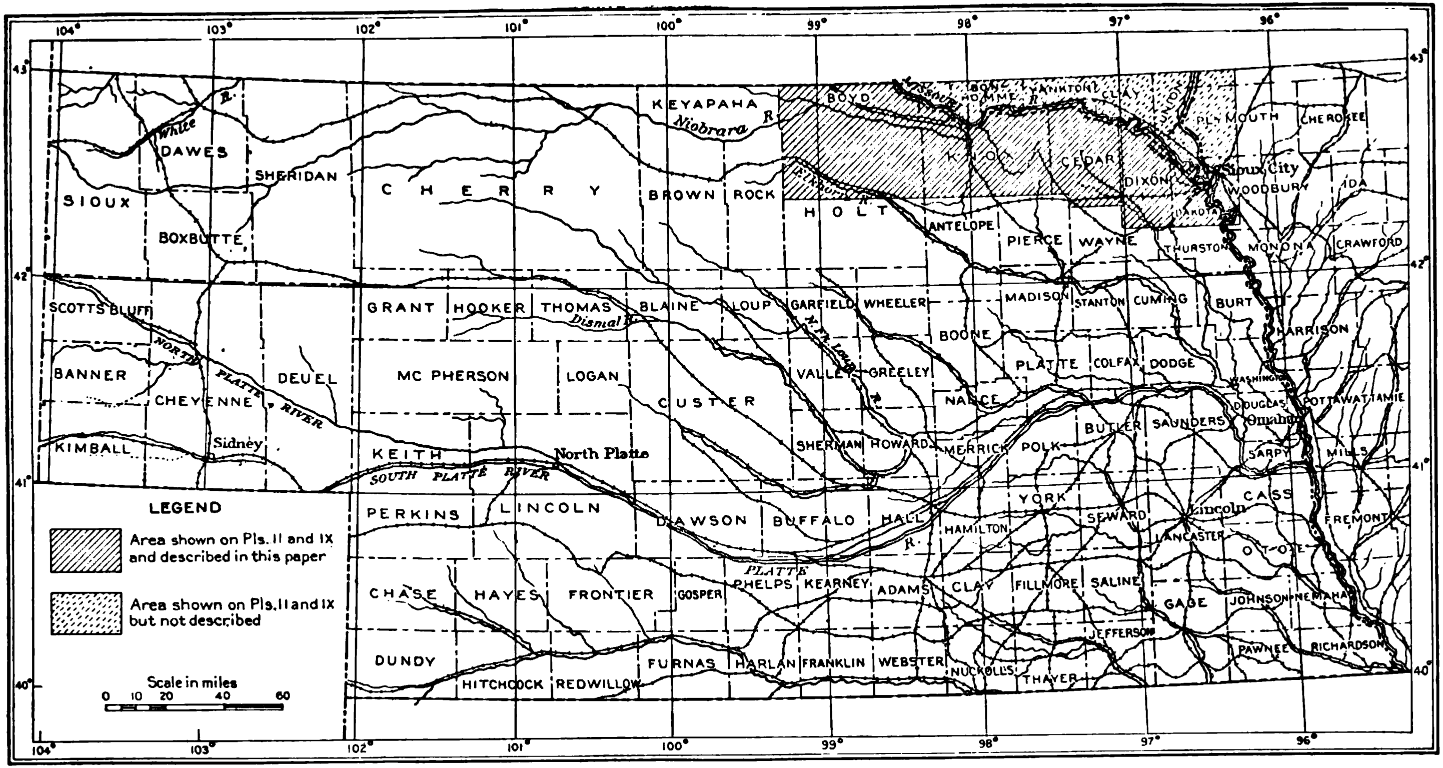
The principal topographic features of the region are the result of the erosive action of streams, but glacial action has modified the surface in some districts by changing the preglacial drainage and adding deposits of gravel, sand, bowlders, and clay, while the wind has modified certain sandy surfaces into small areas of dunes. The altitude varies from over 2,100 feet on the table-lands of western Holt and Boyd counties to about 1,100 feet on the lowlands of Dakota County. The Missouri River, which is the principal stream, has eroded a trough, usually with steep slopes, to an average depth of 500 to 600 feet below the general upland level. The entire area slopes gradually downward from west to east, and more steeply northward from the high divides toward Missouri River. While most of the area slopes and drains northward toward that river, the drainage of small portions of Holt, Knox, Cedar, Dixon, and Dakota counties flows southeastward and reaches the river farther south.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

Study of the local geology of a region affords information concerning the soil, aids in drilling artesian wells by indicating the thickness and character of the formations through which the drill must pass, and is a guide to many natural resources which may be advantageously developed.

The formations in this area are all of sedimentary origin and belong to the Cretaceous, Tertiary, and Quaternary systems. The Cretaceous strata, which are the lowest exposed, consist of beds wide in extent and nearly horizontal in position or with a slight dip to the west. They are composed of clay, chalk, limestone, and sandstone, which were for the greater part marine accumulations of mud, minute calcareous shells, and sand. These formations outcrop extensively along Missouri River and other streams, as shown in Pl. II (in pocket), and by well records their relations at other places are known. The total thickness of the Cretaceous beds in the western part of Boyd County is thought to be about 1,400 feet. From records of deep borings at Ponca and Sioux City it is known that the Carboniferous limestones also underlie the region, beginning at a depth of about 545 feet at Ponca, Nebr., and 335 feet at Sioux City, Iowa.



SKETCH MAP OF NEBRASKA.

The following sections represent the succession at certain typical localities:

Section below the mouth of Aowa Creek, Dixon County, Nebr.

	Feet.
Loess, extends 98 feet higher in slope; exposed	7–30
Glacial till	22
Greenhorn limestone:	
Limestone, slabby, with many remains of *Inoceramus labiatus*	5½
Clay, dark, sandy, with some chalk	1
Limestone, slabby, containing *Inocerami*	4
Limestone, bluish, chalky, weathers to a light color resembling Niobrara chalk rock; contains some *Inocerami*	9
Graneros shale:	
Clay, bluish and somewhat chalky above, dark below, contains iron pyrites concretions, and sulphate of iron as a powder	49½
Clay, dark, at places carbonaceous above, usually sandy, containing concretions of iron pyrites and marcasite and rosettes of selenite	7
Dakota sandstone:	
Sandstone, light to rusty color, porous, and soft; with root marks. Rusty iron concretions occur near the center and base. The beds thicken and dip westward	7–10
Clay, dark, contains irregular streaks of light-colored sand	2½
Sandstone, nodular, contains rusty iron, limy at places	½
Shale and nodules, dark, very sandy near ravine	1
Sandstone, with layers of concretionary iron between beds	4½
Sandstone, rusty and dark, varying from sandstone to shale	5½–6
Sandstone, rusty, porous at 1,120 feet above sea level	

The beds show a steeper westward inclination near the mouth of Aowa Creek, beyond which they appear to rise again for a short distance.

Combined section from Vermilion Ferry to the Dixon-Cedar county line.

No.	Feet.
7. Loess; thick on higher slopes.	
6. Glacial drift; usually covered by loess	0–3
5. Niobrara chalk rock, light color, soft, rises in hills above, exposed in three banks	1–5
4. Clay, dark, with some selenite crystals, sandy at places	13
3. Sandstone and clay, varies from sandstone to plastic clay. Beds carbonaceous at places	8
2. Clay, bluish or dark, plastic, covered with many selenite crystals. Contains two zones of calcareous concretions, one 63–65 feet and the other 55 feet above the river. In one bank a thin bed of rusty sandstone is found 10 feet above the river	73
1. Shale, dark blue, chalky, containing *Serpula*, large, flat *Inocerami*, *Ostrea congesta*, and *Prionocyclus*. Exposed above water	3–4
Altitude of top of No. 1, at ferry	1,130
Altitude of base of No. 5	1,224

All below No. 5 are included in the Carlile shale of the Benton group.

On the eroded upper surface of the Cretaceous lie sheets of sand and clay of Tertiary age, which are thickest and most typically developed in the western parts of Boyd and Holt counties, and thin out in Knox and Cedar counties. The only portion of the Tertiary thus far identified here is the Arikaree formation and an unnamed formation of Pliocene age. A more careful examination of the western part of the region may possibly show the presence of outliers of the White River formation below the Arikaree.

Lying on the eroded surface of the Cretaceous and Tertiary formations, over wide areas, are the deposits of clay, sand, gravel, bowlders, loess, and alluvium of Quaternary age.

STRUCTURE.

In outcrops in northeastern Nebraska the rocks usually appear to lie horizontal, but they have a slight general inclination to the west or west-northwest, which becomes very low for some distance above the mouth of Niobrara River. The principal structural features are shown on the cross sections Pl. III (in pocket). The westerly dip is indicated by the differences in altitude of the top of the Dakota sandstone, which slopes from a height of 40 feet above the river level, or altitude of 1,160 feet, at Sioux City to a depth of 500 feet, or altitude of about 720 feet, at Niobrara. This difference of 440 feet in 80 miles indicates an average dip of 5½ feet to the mile. The dip from Sioux City to Ponca, however, is slight, making the average dip from Ponca to Niobrara about 7 feet to the mile. At Lynch, 23 miles west of Niobrara, the altitude of the top of the formation is about 690 feet, which indicates a fall of only about 1 foot to the mile in that direction, while to the northwest, up the Missouri valley, there is a similar low dip.

DESCRIPTION OF THE ROCKS.

CRETACEOUS SYSTEM.

DAKOTA SANDSTONE.

The Dakota sandstone is of considerable economic importance, furnishing artesian water, brick clay, fair building stone in places, and small amounts of a poor grade of lignite coal.

It outcrops occasionally in bluffs in southeastern Dakota County, Nebr., at Sioux City, Iowa, and along Big Sioux River in Iowa. In Nebraska the formation outcrops at intervals from the high hills southeast of Homer to a point northeast of Ponca, where it passes beneath the river level. It extends far to the northwest and the southwest under later formations and comes to the surface in the Black Hills and the Rocky Mountains. According to well records, its upper surface lies at a depth of 360 feet at Aten, 600 feet at Santee, 500 feet at Niobrara, and 700 feet at Lynch.

The formation is penetrated by wells at Ponca, Nebr., and Sioux City, Iowa, where in each case the thickness is thought to be between

300 and 400 feet. In the Ponca well, 700 feet deep, the base of the formation appears to be at an altitude of about 755 feet, while its upper surface, exposed in bluffs east of the town, rises to 1,135 feet, indicating a thickness of 380 feet; but this estimate probably is somewhat too large.

According to Professor Todd the mouth of the Sioux City well is 38 feet below the outcrops of the sandstone, whose altitude is 1,122 feet, and, as the bottom of this sandstone, according to the well record, is at an altitude of 825 feet, the thickness is 335. It is thought, however, that the beds observed near the mouth of the well are not at the top of the formation and that some higher strata have been removed by erosion.

The Dakota formation is composed largely of thick deposits of coarse friable sandstone, light buff to rusty in color, with interbedded clay beds of different colors, mostly blue, gray, and yellow. One thick bed of clay north of Sioux City overlies the massive cross-bedded sandstone which outcrops along the river banks in that vicinity. Numerous iron-oxide concretions abound in the clay, as do also thin beds of sandstone merging into irregular, sandy iron-oxide deposits of variable thickness. Lignite, in thin irregular beds, occurs in the upper part of the formation, and also at lower levels near Jackson and Homer. Many well-preserved leaves are found which have been studied and described by various paleontologists.

The component beds of the Dakota formation in this region are not sufficiently continuous, extensive, nor distinctive to afford a basis for subdividing the formation into different horizons, yet in the outcrop area the following order has been observed, passing downward: (1) Porous sandstone with root marks, interstratified clays, and shale or lignite beds; (2) clay, thin sandstone, and concretionary ironstone beds; (3) massive, cross-bedded sandstone with thin beds of clay.

As the sandstones weather more slowly than the clay beds they often form bluffs (see Pl. IV, *A*), which extend as a more or less continuous escarpment from southeastern Dakota County to a point near Ponca. At cut banks along the river and near the mouths of a few ravines these bluffs form prominent points and buttresses. The topography varies somewhat, the massive sandstone giving sharp outlines and the clay more gradual slopes. Loess and Graneros clay often slide down over these outcrops, concealing the beds.

Section of Dakota sandstone 5 miles southeast of Homer, Nebr.

	Feet.
Thin beds of sandstone and clay, colored by iron	18
Sandstone, massive, cross-bedded. These beds vary much in texture; within a few feet they may grade from sand into sandstone and even quartzite. The colors are light gray, rusty, and dark	19

Section of Dakota sandstone and overlying loess at the quarry just northwest of Homer, Nebr.

	Feet.
Loess at top of bluff	12
Clay, shaly and oxidized to a yellowish color	2
Sandstone, light colored, porous, massive, not cross-bedded	7
Clay, light colored, concretionary	2
Sandstone, much like No. 6 but with root marks in upper part	10
Clay, light colored, sandy, oxidized; yellowish at places, with hard layers of concretionary iron 1 to 12 inches thick	28
Clay, yellowish, with fewer iron concretions than in No. 3	5
Sandstone, light colored to rusty, massive, cross-bedded, interstratified with thin layers of clay	20

In the Ashford well just west of Homer, the lowest bed of the above section was not penetrated at a level fully 70 feet lower. This member of the Dakota formation rises high in the bluffs some 6 or 7 miles southeast of Homer.

Section of Dakota sandstone and glacial clay in the quarry at Jackson, Dakota County, Nebr.

	Feet.
Glacial clay with some sand	3
Sandstone, rusty	½–1
Sandstone, light colored, loosely cemented	2
Sandstone, rusty to light colored, friable, in beds 2 to 8 inches thick with thin layers of light-colored clay between	8
Clay, sandy, light colored	½
Sandstone, light colored, friable	1½
Sandstone, clay or sand, varying; color rusty to light	3

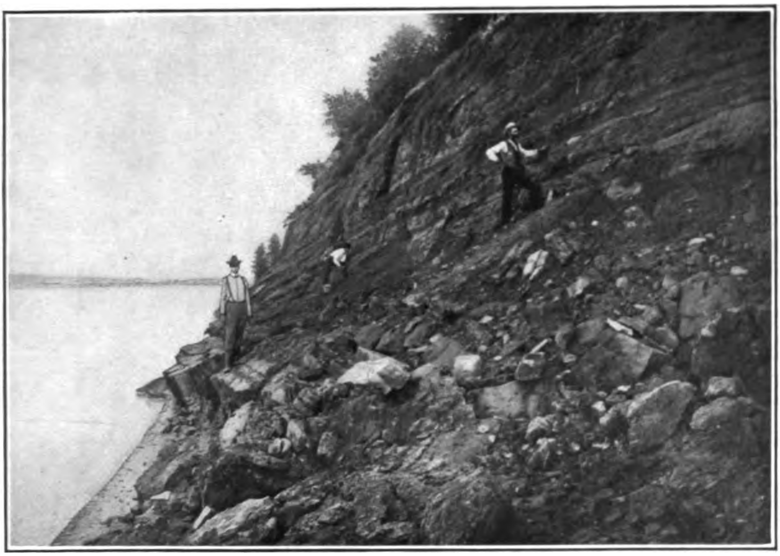
Parts of the stone in this quarry are used for building purposes. Several good specimens of leaves were found here. According to the report of the well drillers a thin bed of impure coal lies 30 feet below the lowest point in the quarry.

Record of Mattison's well, N.E. ¼ S.W. ¼ sec. 20, T. 31 N., R. 6 E., southeast of Ionia, Nebr.

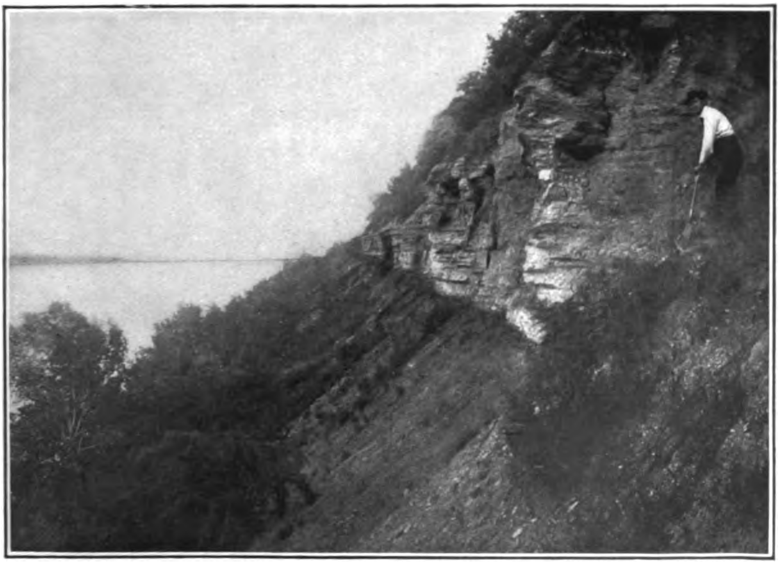
	Feet.
Shaly limestone	0– 8
Chalk	8– 12
Dark shale	12– 45
Blue clay	45–105
Soft sandstone	105–277
Sand and gravel	277–302
Clay or shale	302–312
Soft sandstone	312–487
Gravel	487–517

BENTON GROUP.

The Benton group lies between the Dakota and Niobrara formations and, as Mr. Darton has shown, is separable in this region into three distinct formations, which represent the Graneros shale, the Green-



A. DAKOTA SANDSTONE ON BANK OF MISSOURI RIVER BELOW MOUTH OF AOWA CREEK.



B. GREENHORN LIMESTONE ON GRANEROS SHALE NORTHEAST OF PONCA, NEBR.

horn limestone, and the Carlile formation of eastern Colorado and the Black Hills.

Graneros shale.—The best exposures of the Graneros shale are in river bluffs below the mouth of the Aowa Creek, above Ponca Landing, and at the Bigley Ravine, near Ponca. The shale lies on the Dakota sandstone and is overlain by the Greenhorn limestone. It occurs high in the slopes in Dakota County, and dips gradually to the northwest, its base reaching the level of the river about 3 miles north of Ponca. The thickness in Dixon County is from 50 to 60 feet, while in the Black Hills it varies from 800 to 900 feet. According to Mr. Burchard[a] it appears to thin out and disappear southeast of Homer, where the Greenhorn limestone lies very close to if not directly on the Dakota sandstone. It is composed principally of very dark gray to bluish-gray clay or soft shale which grades above and below into harder shale. The section at the mouth of Aowa Creek (p. 7) shows the usual relations.

Greenhorn limestone.—This medial member of the Benton group lies from 50 to 60 feet above the Dakota sandstone and is 18 to 20 feet thick, not including a few feet of shaly transition beds above and below. The principal rock is fossiliferous limestone with an admixture of clay and some sand. The upper beds are slabby, highly fossiliferous, and stained with iron, while the lower beds are more massive and chalky and contain a smaller number of large fossils. The formation is characterized by very numerous casts of *Inoceramus labiatus* (see Pl. VI). This limestone was traced from high in the hills of southeastern Dakota County to the river level in the Ionia section northeast of Newcastle.

Pl. IV, *B* shows a characteristic outcrop of this limestone. These beds weather out like chalk and were formerly mistaken for the Niobrara chalk rock, which, however, occurs at a higher level farther west.

Section of Greenhorn limestone and associated beds in cut bank and slide three-fourths mile northwest of Ponca Landing, Nebr.

	Feet.
Loess and till	80
Greenhorn limestone:	
Limestone, weathered, sandy; contains many casts of *Inoceramus labiatus*	8–9
Limestone, bluish gray, massive, chalky	10
Graneros shale:	
Clay, bluish, stratified	20
Clay, dark or bluish, at places rusty	25–30
Shale, dark, quite hard	2

---

[a] Geology of Dakota County, Nebr.: Proc. Acad. Sci. of Sioux City, Iowa, 1903–4, vol. 1, p. 150.

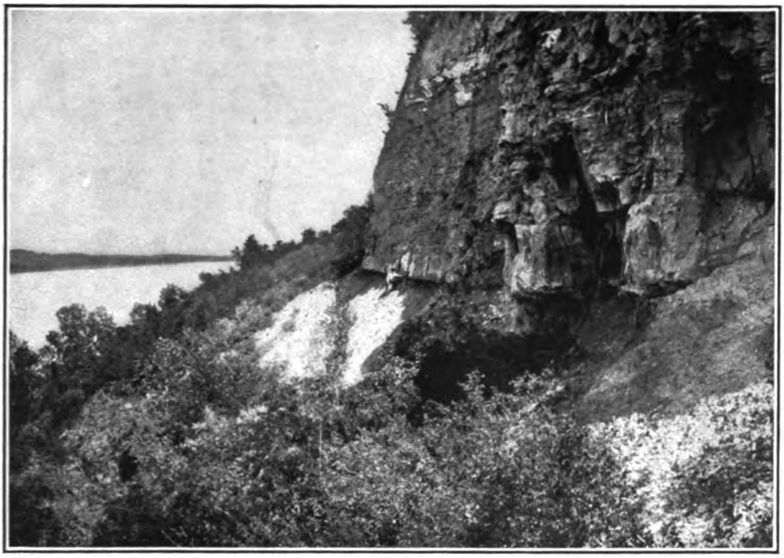
Carlile shale.—This uppermost division of the Benton group begins to appear above the Greenhorn limestone in eastern Dixon County and thickens westward to 170 feet in northwestern Dixon County to over 200 feet at Niobrara, and to 500 to 700 feet in the Black Hills. In the eastern part of its outcrop area it erodes rapidly, forming slopes over which loess and Glacial drift slide from above, concealing it at many points in the bluffs of Dixon County. The base of the formation reaches the level of the river just west of the so-called Ionia Volcano, northwest of Newcastle. The upper surface is about 140 feet above the river level in sec. 28, T. 32, R. 4 E., 97 feet above at Vermilion Ferry, 71 feet above northeast of St. James, 30 feet above north of St. Helena, and reaches the level of the river about 4 miles beyond the last-named town. Recent slides northeast of Ponca expose 8 to 12 feet of Carlile above Greenhorn limestone in the vicinity of the ferry. A well-marked line of contact with the Niobrara chalk above is shown in Pl. V, *A*.

The formation is composed principally of dark-gray and bluish-gray stratified clays, with two zones of fossiliferous chalky shale. Sandstone beds of variable extent and character generally occur at different levels, but usually near the top, as just west of Vermilion Ferry. Large concretions of carbonate of lime are found above the middle of the formation. Drillers in penetrating this formation experience difficulty with the hard concretions and sandstone and with the thin layers of iron pyrites which also often occur in it. Many fish-scales, a large, flat form of *Inoceramus*, *Prionocyclus*, *Serpula*, and *Ostrea congesta* are common fossils.

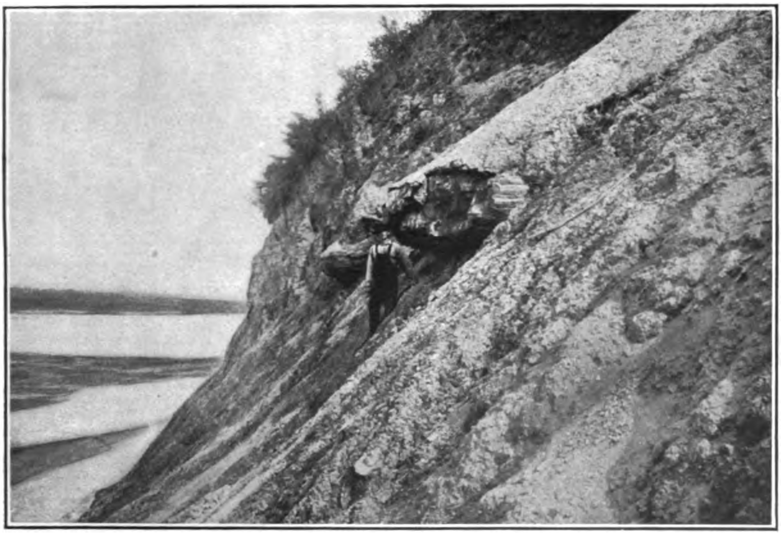
A locality in northern Dixon County, in sec. 10, T. 31, R. 5 E., has received the name Ionia Volcano. It is simply a bluff of shale in which the oxidation of a large amount of iron pyrites often produces considerable heat, at times sufficient to give rise to steam and sulphur fumes, and even to cause slight baking of the shale.

Two zones of concretions of carbonate of lime occur in the Carlile shale. The lower zone is a continuous one, and its concretions are large, lens-shaped forms, 2 to 8 feet long and 1 foot or more thick (Pl. V, *B*). This horizon continues at about 50 feet from the top of the formation from high in the slope in sec. 32, T. 32, R. 5 E., to a point between St. James and St. Helena, where the dip takes it down to the level of the Missouri. The upper zone consists of smaller concretions at a less continuous horizon 8 to 10 feet above the first. These concretions weather out and fall to the base of a slope, where they crack into irregular pieces. In many of them calcite and selenite crystals occur.

While selenite crystals may be observed throughout the Graneros, Carlile, Niobrara, and Pierre, they are most abundant on slopes of the Carlile formation, especially at the Ionia Volcano or on other



A. CARLILE SHALE OVERLAIN BY NIOBRARA NORTHEAST OF JAMES, NEBR.



B. CALCAREOUS CONCRETIONS IN CARLILE FORMATION WEST OF VERMILION FERRY, NEBR.

bluffs in that region, where they are commonly mistaken for mica. They vary in size from minute needles to 2 to 3 inches across. They originate near the surface from the weathering of the iron pyrites scattered through the clay, some of the products of which react with lime in solution in percolating waters, forming calcium sulphate which crystallizes as selenite. The usual belief that they were formed when the strata were deposited and that they occur in large numbers throughout the beds is therefore erroneous.

Section of Carlile shale and associated formations at the Ionia Volcano, in northern Dixon County, Nebr.

	Feet.
Loess and till	15-35
Clay (Carlile), dark, plastic. Contains sulphate of iron, epsom salts, selenite crystals, etc., over the surface. Sulphur dioxide fumes rise from the clay at one point	112
Shale, bluish	15
Limestone, slabby, with fish scales and *Inoceramus labiatus*	1½

Altitude of river, 1,118 feet; of top of hill, 1,265 feet.

The lowest bed is a part of the Greenhorn, while the overlying bluish shale is a transition to the base of the Carlile. It is prominently represented in a ravine below the old landing about 1 mile away.

Professor Todd has noted the existence of a thin but very persistent layer of clay closely resembling bentonite near the middle of the Carlile formation. It varies from 1½ to 3 inches thick. At Vermilion Ferry it is about 10 feet above the river. At the Ionia Volcano it is about 100 feet above the top of the Greenhorn beds, and it is at same horizon in ravines in the SW. ¼ sec. 26, T. 31 N., R. 5 E., and in a shaft in the SW. ¼ sec. 24 of the same township. It is suggested that it may originally have been a thin stratum of volcanic ash.

NIOBRARA FORMATION.

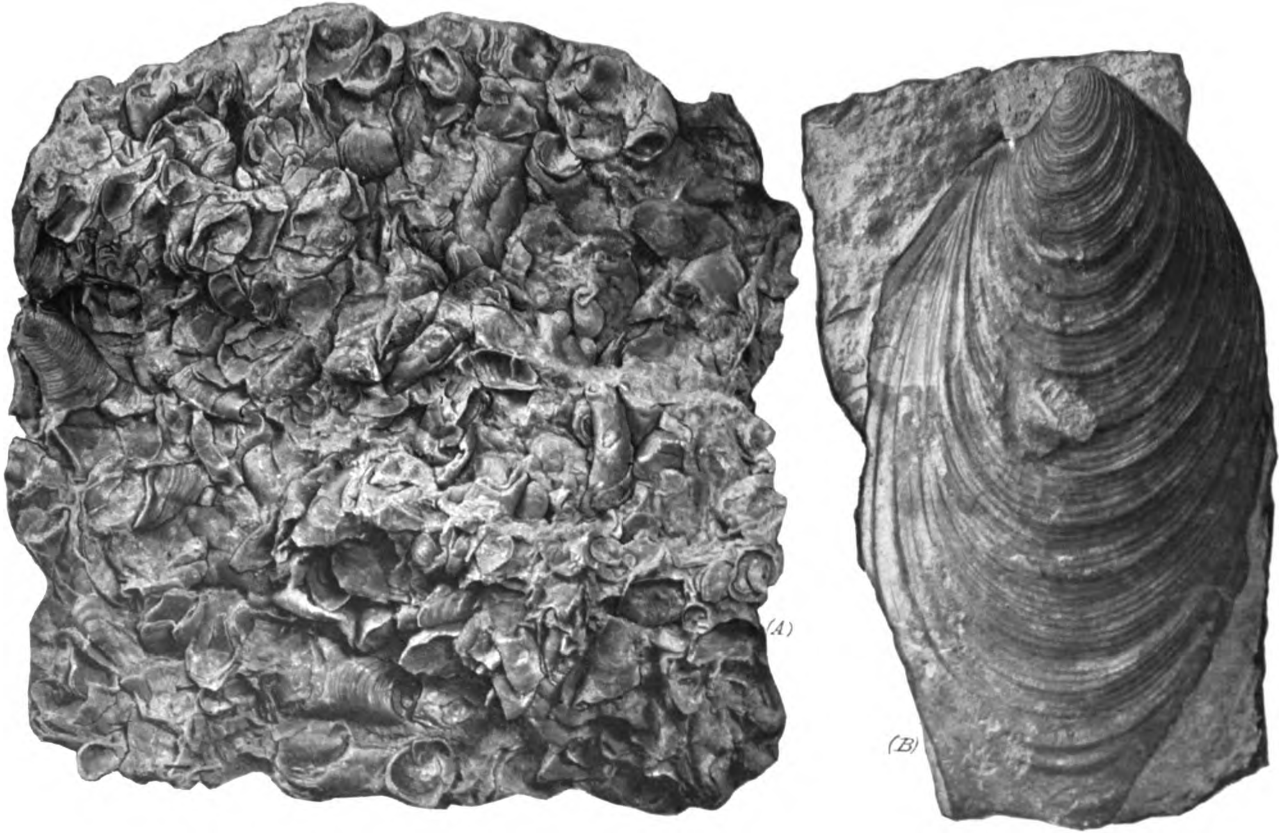
The Niobrara formation lies between the Carlile and the Pierre shales and is a conspicuous and characteristic feature of the region. It outcrops in the creek slopes of northwestern Dixon County, high in the river bluffs just west of Vermilion Ferry, and thence westward and northward along Missouri River and its tributaries to the great bend of that river in South Dakota. A thickness of about 130 feet remains in the hills northeast of St. James, Nebr., while westward at the margin of the Pierre shale the total thickness is over 200 feet. The easternmost points at which the formation is exposed or found in wells are in the SE. ¼ SW. ¼ sec. 32, T. 32 N., R. 5 E., and the W. ½ sec. 6, T. 29 N., R. 5 E. The dip, which is westerly, is low from St. James to Niobrara, beyond which the upper surface seems to be nearly level with perhaps a slight rise in the direction of Chamberlain, S. Dak. The base of the formation is 97 feet above the river near Vermilion Ferry, 71 feet northeast of St. James, and 30 feet at St. Helena, a few miles beyond which it passes below the level of the river. At the cement works west of Yankton, S. Dak., the upper surface is fully 140 feet above the river surface, while the base lies a few feet below it.

The formation is composed of lead-gray chalk rock, which weathers yellowish, with a variable admixture of clay and sand. Thin limestone beds composed of small *Ostrea congesta*, found principally in the upper portion, are a characteristic feature (see Pl. VI). In Cedar County and apparently at Niobrara, Knox County, the base of the formation is a sandy, hard limestone. The purer chalk beds vary from less than 1 inch to as much as 6 feet in thickness and merge into mixtures of chalk and clay in variable proportions. The upper surface is usually weathered, leaving a relatively larger percentage of clay, iron, and sand than is found in the more massive beds below. In the latter there are nearly vertical joint planes intersecting each other at angles of about 90 degrees. Deeply decayed surfaces have gypsum plates in the joint and bedding planes, and at places selenite crystals are scattered over the surface. The purer massive chalk is of fine grain, porous texture, low specific gravity, and gives a characteristic dead or hollow sound when struck with a hammer. Its economic value lies in its use for the manufacture of cement and for building stone.

The chalk bluffs of the Missouri present a strikingly barren appearance and are usually of a conspicuous yellow color. The bluffs have a uniform height above the river for a distance of over 200 miles in Nebraska and South Dakota, but are notched by many small draws. The upper surface of the formation falls to within 8 or 10 feet of the river at Wheeler and Nieveen, S. Dak. For most of the distance, from a point 5 miles below Greenwood to Yankton, the Niobrara bluffs are prominent on one side of the river or the other. At a number of places slight faults and flexures were observed; most of the latter occur at the mouths of small ravines and appear to be caused by the swelling of beds. The steeper slopes are often covered with splinters of chalk rock broken from the cliffs above.

Section of Niobrara limestone and associated formations northeast of St. James, Nebr.

	Feet.
Loess. Rises in hills to an altitude of over 1,400 feet	40–50
Niobrara chalk, massive, somewhat sandy, and harder in lower beds. Base at 1,205 feet above sea level. Rises in hills to an altitude of 1,335 feet, or a thickness of 130 feet exposed	40–50
Carlile clay, dark and bluish, with some sand and sandstone. Large calcareous concretions 50 to 55 feet below top. Exposed in slope to river	71



CHARACTERISTIC FOSSILS OF NIOBRARA FORMATION AND GREENHORN LIMESTONE.

A, Ostrea congesta; *B*, Inoceramus labiatus.

Section of Niobrara limestone and Pierre shale on Bazile Creek at bend in road 1 mile south of Bazile Point, Nebr.

	Feet.
Pierre shale:	
Carbonaceous clay, dark in bank, lighter on weathered surface, which is strewn with selenite crystals and small yellowish concretions of irregular form	6
Niobrara:	
Weathered chalk, yellowish, with 3 or 4 light-colored streaks 2 inches thick and about 1 foot apart, *O. congesta* present	7
Chalk, beds irregular, sandy, and at places concretionary; gypsum plates occur in bedding and irregular joint planes. Lower beds 6 to 8 inches thick. *O. congesta* is the common fossil	8½
Blue chalk, lower 4 feet in 2 beds; large *Inocerami* and *O. congesta* present	8

Analysis of Niobrara chalk rock.

[Howison Crouch, analyst.]

	Unweathered specimen.	Weathered specimen.
Moisture	0.70	1.11
SiO_2	4.52	6.02
Organic matter	3.14	1.03
SO_3	2.14	.85
CO_2	37.80	37.11
CaO	49.66	47.98
FerO$_3$ and Al_2O_3	1.87	5.92
Mg	Trace.	Trace.
	99.86	100.02

PIERRE SHALE.

The Pierre shale is the thickest member of the Cretaceous in Nebraska, varying in thickness from a few feet in northwestern Cedar County to over 500 feet in western Boyd County. The base, lying on the Niobrara, slopes down slowly from western Cedar County to central Knox County, beyond which it is either horizontal or has a slight rise westward. The eroded top reaches an altitude of over 1,900 feet in western Boyd County. At the cement works, 4 miles west of Yankton, S. Dak., the Pierre clay just above the Niobrara chalk is distinctly crumpled, a feature which may have been caused by the ice sheet.

During Eocene and early Miocene times this region was a land area eroded into hills and valleys. The Pierre clay was entirely removed in the eastern part, and on the rough upper surface later Tertiary and Quaternary deposits were laid down, to be themselves in turn partly removed by weathering and erosion.

The Pierre shale is commonly called "gumbo" and "soapstone," and consists principally of dark and bluish, plastic, and finely stratified clays. It carries lenses of limestone, and beds of shale, impure chalk, and thin layers of concretionary ironstone. At its base there is a dark carbonaceous clay, resembling coal, which is exposed along the Missouri, beginning in irregular lenses near Chamberlain, S. Dak., and extending as a continuous, well-marked horizon from a few miles farther down the river to eastern Knox County. At the latter place it contains, near the middle, an admixture of whitish clay, resembling fuller's earth and varying in thickness from 10 to 30 feet or more. The next horizon above is made up of dark and bluish plastic clays with thin seams of iron ore. Above this are alternating beds of shaly chalk and clay, the former weathering reddish; these chalky beds are often mistaken for Niobrara chalk. The highest beds of the Pierre, as observed in Boyd County, are bluish clay with some concretions of iron ore. The sections on page 17 give the strata more in detail.

The Pierre shale in this region is not rich in fossils. A few *Inocerami*, shark's teeth, and mososaur remains were observed by the writer. Mr. R. F. Stout, Center, Nebr., has collected from Pierre chalky beds about 72 vertebræ, the paddle bones, and pieces of ribs of a very large mososaur. He also secured crocodile bones and a number of *Belemnitella.*

The beds do not rise steeply in bluffs but, weathering rapidly, form rolling hills and long slopes. A typical hilly country of Pierre shale lies between Santee and Herrick in what is called the Devil's Nest. The hills, though usually either grass-covered or farmed where not too rough, show light to dark bands at different levels. This appearance is due to the alternation of beds, the chalky deposits causing light bands, the chalk stained with iron giving rise to yellowish soil, and the dark clays and iron-bearing beds giving brownish and dark streaks.

In the high ridge just north of Niobrara River and southeast of Spencer, certain hard beds at different levels cause flat summits or a series of irregular steps rising from east to west. The topography of the different zones of the Pierre is well shown along Bazile Creek, which has a grade of about 400 feet in 24 miles. Gradual clay slopes extend from altitude 1,560 to about 1,500 feet; steeper, chalky slopes with a narrower valley extend from altitude 1,500 to 1,400 feet; while the clays below give more gentle slopes and a wider valley down to about 1,280 feet, at which altitude the Niobrara chalk begins and bluffs prevail.

A very noticeable feature, especially in northern Holt County, is the presence along Niobrara River and its tributary creeks of many landslides, caused by the infiltration of ground water through joints in the clays, rendering them plastic. Fully 50 slides may be seen along Eagle Creek, between Turner and Ray, where Pierre clay rises from 60 to 100 feet in the slopes. At John Dolin's place, in sec. 26, T. 32, R. 11, a slide formed in 1893 has a length of 20 rods and vertical displacement of from 50 to 100 feet. It completely dammed Eagle Creek, causing the channel to shift several rods southward.

Section of Pierre shale along Bazile Creek ¼ mile southeast of Mackeyville, Nebr.

	Feet.
Bluish clay with flakes of iron oxide on surface	79
Dark, carbonaceous clay which, at places, is chalky, extending below the water in the creek	12

Section of Pierre shale and Niobrara limestone south of the Missouri River and 3 miles west of Fort Randall, S. Dak.

	Feet.
Pierre shale:	
Clay with ironstone over surface; some selenite above	13
Clay, yellowish, chalky, varies in character from massive, impure chalk to large concretions of chalk and clay. Dark, flat concretions occur at base	11
Clay, very dark; carbonaceous with thin, light-colored seams at base; definitely jointed, standing as buttresses, between which it weathers into amphitheater-like recesses; surface lighter where weathered; gypsum flour and selenite in joint and bedding plains. Lemon-yellow concretions occur near top of beds	28
Niobrara:	
Chalk, weathered above, darker below; with few fossils	40

Section of Pierre shale and overlying deposits, one-half mile northeast of Center, Nebr.

	Feet.
Loess	4
Sandy slope	9
Pebbles and gravel, then fine sand and glacial pebbles at base	30
Pierre shale:	
Dark clay, somewhat chalky when dry	1½
Light buff-colored clay, bedding not plain, showing gypsum flour and small selenite crystals in joint and bedding plains	4½
Clay, light, blue, or dark at places; chalky and hard. Rosettes of selenite common over upper 2 feet. Gypsum flour in cracks; crystals in joint and bedding plains	19
Clay, dark gray	2
Clay, dark, plastic, with 3 to 6 inch zone of oxidized iron concretions 32 feet below top. This clay seems to extend below the creek. Exposed	45

Section of Pierre shale above the Whiting Bridge, 7 miles southeast of Spencer, Nebr.

	Feet.
Clay, dark, plastic, with thin seams of iron	170
Yellowish clay, darker where not weathered, with some portions bluish	40
Chalky beds, at places hard enough for building purposes	2
Alternating dark shale and clay; the shaly beds stand out as buttresses	36

Altitude of river, 1,502 feet; top of slope, 1,750 feet.

TERTIARY SYSTEM.

Two formations of later Tertiary age occur in this region: one is the Arikaree, which has a wide range over western Nebraska and adjacent States; the other, which has no name, consists of certain stratified sands and clays found in Holt, Knox, and Cedar counties.

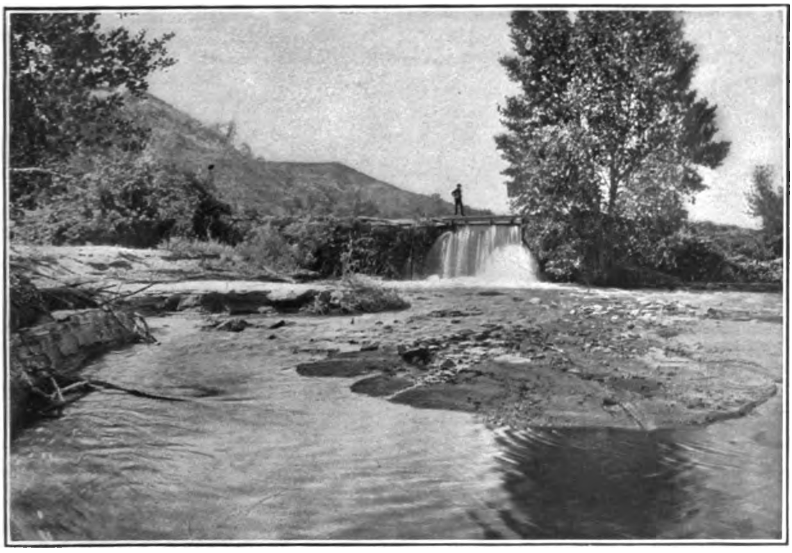
ARIKAREE FORMATION.

The Arikaree formation is composed of grayish sand and sandy clays, with local beds of sandstone, quartzite, conglomerate, and fresh-water limestone, which, in the table-lands of Boyd, Holt, and Knox counties, are 100 feet or more thick. From these nearly level areas the formation thins on the slopes and ridges toward and between the streams. Certain outliers in the eroded areas give rise to buttes of more or less prominence. Originally the formation extended over all of the western part of the region to which this report relates and well into Cedar County and perhaps farther east, but by subsequent erosion it has been widely removed, leaving only a few remnants, capping buttes on some of the northwest-southeast trending ridges to the east.

The sandy portion of the formation is in part unconsolidated, the grains usually being feebly cemented by a small amount of calcium carbonate. Where there is more complete cementation there are local beds of sandstone which generally show cross-bedding. In several cases the rock contains pebbles. In most of the buttes there occurs a hard, greenish sandstone or quartzite with a silicious cement, identical with that found in the Bijou Hills of South Dakota and at Woodruff, Kans. These hard beds do not occur at definite levels, the nature and kind of the rock often changing within a few feet.

Not many fossils are found in the Arikaree formation. Silicified wood is abundant on the place of Andrew Lukup, southwest of Verdigre. Several mammalian bones have been found about the buttes, but the writer saw only one bone of that class embedded in the rock. The most conspicuous outcrops are in the well-known Twin Buttes, 10 miles west of Butte, Boyd County (Pl. VII, *A*), and Stony Butte, 2 miles southwest of Verdel, Knox County. Twin Buttes, 2,060 feet in altitude, are so prominent that they can be seen for many miles, even from points in South Dakota beyond Missouri River. From the top of the southeast butte, which rises over 100 feet above the plain, a good idea can be gained of the former extension of the Arikaree table-land north in Dakota, west in Keyapaha County, and south in Holt County. The altitude of Stony Butte is about 1,700 feet; in it the Pierre clay is capped by 25 feet of Arikaree formation, the latter being composed of cross-bedded sandstone and quartzite, with a small amount of sand at the base. As

A. ONE OF THE TWIN BUTTES, BOYD COUNTY, NEBR.



B. KNOLLKEMPER DAM, TURNER, HOLT COUNTY, NEBR.

this sand crumbles out or washes away, the hard beds above are undermined and break into large pieces or bowlders which scatter over the Pierre slope below.

Section of Tertiary deposits in bluffs northeast of Badger Bridge, Boyd County, Nebr.

	Feet.
Sand and gravel in slope	38
Sandstone, quartzitic, greenish to light, cross-bedded, weathers to light color	2
Sandy loam, grayish, light on surface, darker in bank; not plainly stratified; contains in upper part hard concretions 6 to 8 inches in diameter. These break into irregular pieces showing dendritic structure	7
Loam, grayish, sandy, weathers to a yellowish or buff color, resembling loess; lies on Pierre shale at an altitude of 1,800 feet	62

Section of Tertiary deposits at the southeast Twin Butte, Boyd County, Nebr.

	Feet.
Sandstone; 3 feet top of grayish to greenish and quartzitic, the rest friable, cross-bedded, and showing plant-like tubes	10–15
Gray sand	5–10
Porous rock consisting of sand and pebbles in a limy matrix	6–10
Clayey sand, greenish in beds, grayish on surface	90?

In a field just north, and at the top of the bluffs along Keyapaha River, this lower sand is underlain by a bed of greenish quartzite, beneath which is a bed of loam lying on Pierre clay.

PLIOCENE DEPOSITS.

At the close of Arikaree time the region was extensively eroded by drainage, which for a while at least flowed from northwest to southeast. A few remnants of the deposits of these old, high-level streams may be seen extending southeast across Gregory County, S. Dak., and at other points farther west. The longer axes of the buttes of Arikaree formation in Boyd County extend in the same direction. Parts of northeastern Nebraska were considerably eroded at this time, but finally received the sand and gravel deposits which are thickest to the east and south. The old channels extending across Knox and Cedar counties and described by Prof. J. E. Todd[a] may have been outlined at that time, for they appear to be related to the old channels farther northwest. Old valleys connect Ponca Creek and Niobrara River in secs. 25, 26, and 36, T. 34 R. 14, and south of the buttes near Butte. Sandy gravel-capped ridges trending northwest-southeast, with intervening dry valleys, occur at various places, notably southwest of Butte.

The so-called Pliocene deposits consist principally of stratified sand with some gravel and clay, which comes to the surface in southeastern

---

[a] Todd. J. E., Moraines of southeastern South Dakota: Bull. U. S. Geol. Survey No. 158, 1899, pp. 6061.

Holt and southwestern Knox counties and lies beneath loess and glacial drift in much of Knox and Cedar counties. The best typical exposures occur in the Devils Nest region between Santee and Herrick, where a thickness of 50 to 100 feet has been observed. The relations of these beds to the Arikaree drift and loess has not been fully ascertained; while they are usually described under the name Pliocene it seems highly probable that the accumulation of much of the formation so characterized extended well into Quaternary time.

QUATERNARY SYSTEM.

Deposits belonging to this system consist of glacial drift, loess, alluvium, and dune sand.

GLACIAL DRIFT.

The drift is composed of irregular masses of bowlder clay and of sand and gravel beds with an admixture of bowlders at places, these materials having been carried to the region by the glacial ice sheet and streams. The bowlder clay is exposed lying on the Cretaceous and Tertiary deposits at various points along the deeper valleys, and is reached in wells at a number of places; it frequently contains northern pebbles and bowlders. Gravel and sand beds are of wide extent under the loess; they rise to an altitude of over 1,600 feet in northwestern Knox County, where they mix with somewhat similar materials of western origin. Along some of the principal streams the gravel beds appear as a terracelike cap. Bowlders occurring in connection with the gravel are found along the streams and on hill slopes in Knox and Cedar counties, where, as a result of undermining, they fall or roll to lower levels: one of the most conspicuous deposits extends from 1 to 3 miles north of Hartington. In Dixon and Dakota counties they seem to be buried beneath the loess and to be in small numbers, as well drillers rarely find them. The western limit of northern drift extends from near Verdel southward along Verdigris Creek.

LOESS.

This important surface formation, often called the Bluff deposit, extends over most of Nebraska east and south of the sand hills, and into Iowa, Missouri, Kansas, and other States. It is composed of fine sand and clay particles and contains a small amount of calcium carbonate which holds the grains together loosely. The nearly universal buff color is due to the presence of a small amount of yellow oxide of iron. The thickness varies from a few feet to over 100 feet. Its most noticeable feature is the uniformity of porous texture and massive structure throughout, with only occasional traces of stratification. In western Knox County the loess becomes sandy or changes to a loesslike silt. A close examination of a loess bluff shows faint vertical cleavage and usually the presence of small, light-colored, irregular concretions. Very small shells, usually of land forms, occur at many localities.

The origin of the loess is still a disputed question, some geologists holding that it is a wind deposit, while others claim that it has been deposited in water. From its character and relations in this region, it seems probable that the principal agency has been wind, but the deposits were locally modified by water.

The eastern part of the area described in this report has a hilly loess topography. Near Ponca many vertical slips due to the vertical jointing were observed in the hills, where they are locally called "cat steps." The vertical displacement causes the formation to slide over and cover banks in which older formations occur. Where the talus is removed from below by a stream or other agent, nearly vertical loess bluffs result.

Near Cook Creek, close to the east side of the Santee Indian Reservation, a loess escarpment begins as a bluff rising from 100 to 200 feet above the Cretaceous clays in the Devils Nest below. This high ridge extends southeastward and then curves northeastward to a high hill 4 or 5 miles southwest of St. Helena. The noticeable feature is that the slope is southward from the brink of this escarpment. The loess similarly slopes away from the brink of the Missouri Valley just south of Vermilion Landing, Cedar County.

ALLUVIUM.

Alluvial deposits composed of sand, clay, and some gravel, floor the principal valleys. These deposits have also been called valley wash and bottom land, while their upper surface is referred to as a flood plain. Level areas of the same nature but somewhat higher, are called benches or alluvial terraces. The alluvial flats along Missouri River vary in width from about 2 to over 10 miles, being widest along Dixon and Dakota counties; between Jackson and Homer they form the extensive bottom lands.

Alluvial materials comprise flood-plain and alluvial-fan deposits. The former have been deposited principally by the Missouri, while the latter, which are well shown between Ionia and Ponca, have been carried from adjacent slopes by weak tributaries, and scattered over the flood plain at the mouths of ravines. The thickness of the alluvium averages much greater than the depth of the river channel; a thickness of 185 feet is reported in the Joseph Holtzbauer well near Aten.

The bottom lands along the Niobrara average from one-half to three-fourths mile wide and are very sandy. Nearly all of the smaller streams flow on narrow beds of alluvium.

DUNE SAND.

In certain areas the wind has blown Arikaree, Pliocene, and alluvial sands into small dunes or sand hills. The principal area lies south of Niobrara River, and is from 5 to 8 miles wide, extending from the western part of Holt County to near Bazile Creek. A few small " blow-outs " occur on the highland west of the town of Verdigre. Low sandy ridges, extending in a northwest-southeast direction, occur at several points in Knox and Cedar counties; they were formed earlier than the dunes on the alluvial flats. At a number of places the loess is completely covered by drifting sands. A few small dunes are found on the Logan Creek bottom, near Laurel.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

BRICK CLAY.

Cretaceous clays and the loess are used successfully in the manufacture of brick. Twelve brickyards were operating in the region in 1903.

SAND AND GRAVEL.

Building sand in unlimited amounts is found along Niobrara and Missouri rivers, and is plentiful in the Tertiary and Quaternary formations. The principal loading station is at Stewart, Holt County, where the sand is scooped onto cars and sent out by trainloads. Gravel suitable for ballast occurs in terraces and in the glacial deposits at many places. Glacial bowlders have been used as foundation materials.

BUILDING STONE.

No very attractive and durable stone is found in northeastern Nebraska, and that available occurs under unfavorable conditions. The stone most used is the greenish Arikaree quartzite described on page 18. It is hard and fairly durable, but works in poor form, as the deposits are of very irregular character. It is quarried in most of the stony buttes and at a few lower levels, and is used principally for foundations and milldams. Most of this material is obtained (1) from many places in northern Holt County, as at Ray and Turner, where it is found in residual bowlders; (2) at John Vicknish's quarry, near Ray; (3) northeast of Badger Bridge; (4) in the vicinity of Twin Buttes; (5) just south of the town of Butte; (6) 3 miles north and one-half mile west of Spencer; (7) at the Stumbo quarry, in sec. 20, T. 33, R. 10 W., between Lynch and Gross; (8) on the divide south of Monowi; (9) on Stony Butte, 2 miles south of Verdel; (10) 6 miles southwest of Verdigre; (11) on the divide between Verdigre and Center, and (12) 2 miles southwest of Aten. The quartzite is excellent for concrete work and it would make very fair ballast if crushed.

The Greenhorn limestone is used somewhat for foundations, and the Niobrara chalk, though soft, serves fairly well as a building material where it can be placed above ground water. In some houses it has stood over twenty years with little sign of decay. The Menominee Church, in northern Cedar County, and the house of C. D. Buhro, sec. 20, T. 32, R. 2 W., Knox County, are good examples of this.

The lens of limestone in the Pierre formation 7 miles northwest of Verdigre has been used to some extent as a source of building stone, but there is only a limited supply of it and considerable stripping is necessary.

At Jackson, Homer, and a point 5 miles southeast of Homer, a fair grade of sandstone is found in the Dakota, but the conditions for quarrying are not favorable.

CEMENT ROCK.

A large portion of the chalk rock of the Niobrara formation is suitable for cement manufacture and, with the growing demand for Portland cement, the production of this material may prove profitable in northeastern Nebraska. It is now manufactured extensively across the river in South Dakota, in mills located 4 miles west of Yankton and 1½ miles north of the river. The plant has been running thirteen years, supplying cement to South Dakota, Iowa, Nebraska, and other States; the output is 300 barrels a day, with 60 men working. The materials used average about 4 parts of Niobrara chalk to 1 part of Pierre clay. The top of the chalk here is weathered and has to be stripped to a depth of about 15 feet. The chalk and clay are mined or quarried, crushed together, thoroughly mixed, and then carried by water slushes to drying vats, where the mixture is dried by solar heat, and separated into blocks. Then come kiln burning, final grinding, and preparation for shipment. A view of the works is shown in Pl. VIII, *A*.

The formations worked at Yankton are exposed in Nebraska along Missouri River from Dixon County to northern Boyd County and afford a vast supply of the raw materials. The principal factors to be considered in the establishment of a plant, besides the presence of suitable cement materials, are the condition in which they are found so as to avoid waste in quarry strippings, the water supply, fuel, and a suitable location, especially in relation to transportation facilities. All of these conditions except cheap fuel exist at many places on the Nebraska side of the river. At Niobrara the chalk rock is of good quality and in large supply, and this place is favorably situated for railroads and river transportation; artesian water and a suitable location for a plant can also be had. A view of an outcrop at this place is shown in Pl. VIII, *B*.

COAL.[a]

For nearly fifty years there has been more or less prospecting for coal in northeastern Nebraska, but the results have been most unsatisfactory. Near Ponca Landing, from 10 to 18 inches of an inferior grade of lignite is found in the basal portion of the Graneros shale, and it has been worked in a limited way. Near Jackson two holes were recently sunk, which found two thin beds of lignite in the Dakota. In a high bank southeast of Homer a thin bed of lignite rises 85 feet above the river. Paying quantities of coal are not to be expected in this region. The following analyses of Dakota County lignite, by Mr. E. F. Burchard, may be of interest in this connection:

Analysis of air-dried lignite from near Jackson, Nebr., at a depth of 65 feet.

[E. F. Burchard, analyst.]

Water	4.03
Volatile matter	51.40
Fixed carbon	33.66
Ash	10.91
	100.00

Sulphur undetermined.

Analysis of air-dried lignite from shaft near Jackson, Nebr., depth 82 feet.

[E. F. Burchard, analyst.]

Water	6.47
Volatile matter	27.24
Fixed carbon	49.27
Ash	16.23
Sulphur	.86
	100.07

PEAT.

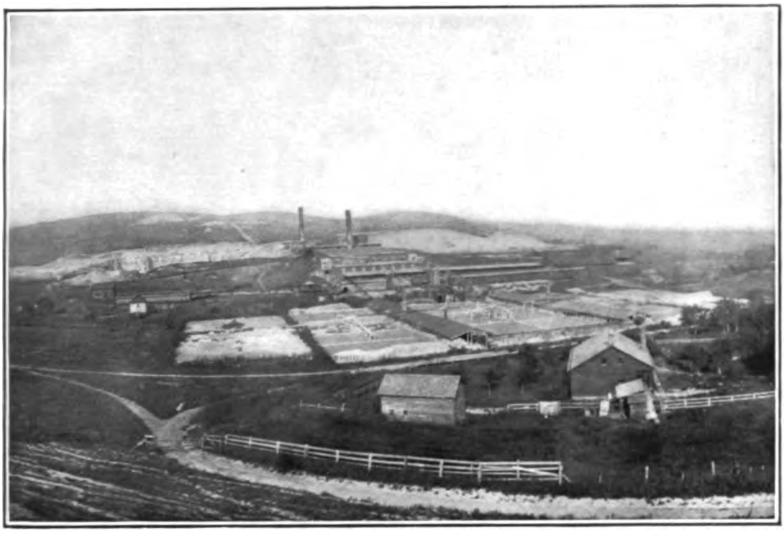
While there has been no development of peat as a source of fuel in any part of the area, it seems probable that it may be found in considerable quantities in some of the boggy basins. One of the localities that should be investigated is the basin of Perrin Creek, in Cedar County.

VOLCANIC ASH.

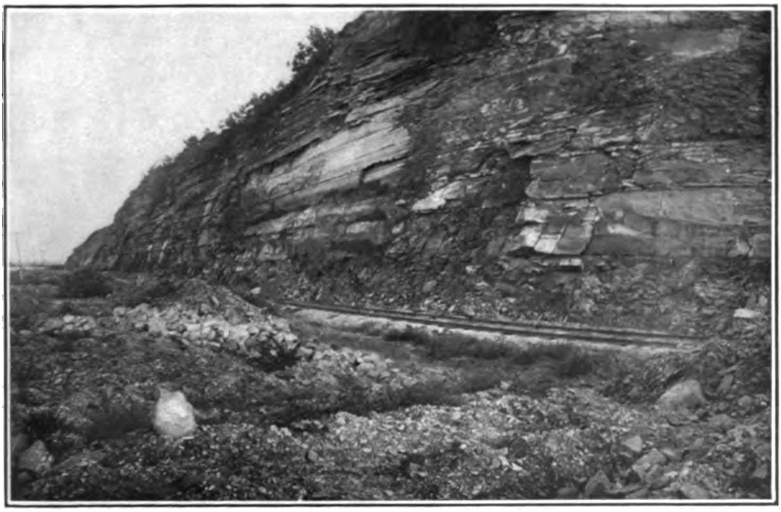
Volcanic ash beds which may yet prove of some importance occur in Holt, Knox, and Dixon counties.

---

[a] Extended accounts of the lignites of Dakota County are given by E. F. Burchard in Contributions to economic geology for 1903: Bull. U. S. Geol. Survey No. 225, 1904, pp. 276-288; and in Geology of Dakota County, Nebr.: Proc. Acad. Sci. and Letters of Sioux City, 1903-4, vol. 1, p. 150.



A. CEMENT PLANT NEAR YANKTON, S. DAK.



B. NIOBRARA FORMATION JUST WEST OF NIOBRARA, NEBR.

WATER RESOURCES.

GENERAL STATEMENT.

Of the water which falls upon the land, part runs off into surface streams, part evaporates, and part is absorbed by the land and by plant growth. The proportions vary with the rainfall, soil texture, geologic structure, and topography, the volume of rainfall being the most important factor. In northeastern Nebraska the rainfall varies considerably in the different counties, with a general diminution from east to west, the normal annual precipitation ranging from 27 to 28 inches in Dakota, Dixon, and Cedar counties to less than 23 inches in parts of Boyd and northern Holt counties. Mr. George A. Loveland, meteorologist at the University of Nebraska, gives the following data:

> Normal annual precipitation at Agee, Holt County, 23.87 inches; Lynch, Boyd County, 23.33 inches; Santee, Knox County, 22.78 inches; Hartington, Cedar County, 27.53 inches; Elk Point, South Dakota, 27.61 inches. The maximum amount of rainfall is in May and June, or during the growing season. Nothing definite is known concerning the amount of evaporation from different soil surfaces in this section. The maximum evaporation is during June, July, and August.

The absorbent power of the soil is greatest in the loess and sandy areas which occupy much of the area. On certain clayey soils on steep slopes the run-off is large, notably on some of the Pierre lands. Water absorbed and collected in the soil is called ground water; it moves slowly downward until it reaches some impervious layer, above which it accumulates in varying amounts, in many areas completely filling or saturating thick beds of sand. The ground water moves slowly from higher to lower regions, at a rate which is greatest in coarse or porous beds. Heavy rains raise the upper surface of the ground water, while long dry spells, when evaporation is greatest, lower it.

A few lakes in the sand hills north of Turner show well this rise and fall of the water table, filling up during wet weather and disappearing at dry times. During the dry years 1893 to 1895 the water table lowered very perceptibly, while during 1903 it rose and numerous new springs appeared at the surface. The ground water also is the source of the shallow wells' supply.

SURFACE WATERS.

STREAMS.

The Missouri River carries a large volume of water, and although its grade is less than 1 foot to the mile it flows rapidly. It is important as a source of water for drinking, domestic purposes, and stock. Many persons drink the turbid water as it comes from the river, but in most cases it is settled in vats before using. While it affords a good supply of stock water, many cattle and a few horses are lost each year by falling into the river at caving banks. These unfortunate animals rarely escape, for, although they gain a footing at some sloping bank, they usually can not climb out, and finally die from exhaustion. The Missouri is also an important avenue for transportation by means of steamers of small size, which carry grain, stock, lumber, and passengers.

Niobrara River receives most of its water from springs at the base of the Arikaree formation. The following discharge measurements were made near the village of Niobrara:

Discharge, in second-feet, of Niobrara River near Niobrara, Nebr.

Date.	Hydrographer.	Discharge.
April 6, 1901	O. V. P. Stout	1,591
April 7, 1901	do	2,115
May 11, 1902	J. C. Stevens	1,637
July 6, 1902	do	2,021
July 25, 1902	do	1,401
August 21, 1902	do	1,106

The stream is shallow and relatively swift, flowing among many sand bars. The water is not deep enough for boating. In this section the south slopes are usually sandy, while those on the north are clayey and very steep. Except for stock and locally for domestic purposes the water is not extensively utilized.

Ponca Creek is a weak stream in a large basin. It heads in south-central South Dakota, in many broad, shallow valleys which carry but little water.

Many water powers available in this region could be utilized to advantage. While power sites are found in each county, the most favorable conditions prevail in Knox and in the northern part of Holt County, where the powers are mostly on the smaller or spring-fed streams, which are not much affected either by floods or dry weather; these have steep grades and keep open most of the winter. As the country becomes more populous there will be increasing demand for water power, which is little used now except to run a few flouring and grist mills.

SPRINGS.

Springs are an important water resource in all the counties, affording most of the local water supply. The principal horizons from which they flow are (1) between the Tertiary sands and the Pierre clay, (2) between Glacial drift and the Pierre, and (3) from the Dakota sandstone.

The porous Arikaree formation contains a large supply of ground water which sinks to the impervious Pierre clay, along the top of which it flows until it reaches the surface on the hill slopes. This condition is shown by the existence of frequent springs at the base of the Arikaree sands, whence the water flows out over the clay slopes below. This horizon lies high on the slopes in the western parts of Holt and Boyd counties and somewhat lower in Knox. In all cases the same general conditions prevail—an impervious bed checking the downward motion of water accumulating in a porous formation, and a lateral flow to the surface. The water from a series of springs often collects into a flowing stream, but, on the other hand, soil often chokes or checks the flow, especially in pasture lands where cattle and horses assist the process by tramping. During exceptionally humid years, ground water reaches the surface at additional places, producing transient springs. These are often called wet-weather springs, and are evidence of extensive seepage not far back in the slope which, by suitable trenching, can often be opened so as to furnish a permanent flow. Sometimes a short horizontal well or tunnel will reach a permanent supply. Where the formation is not too sandy the same result can be accomplished by boring and drilling.

Boggy places, where the ground water seeps to the surface, occur along certain streams in each county. The springs coming from the Dakota sandstone are, in part at least, seepage from the artesian waters, a portion of which reaches the surface in the eastern part of the area to which this report relates.

UNDERGROUND WATERS.

SHALLOW WELLS.

Shallow wells, like most springs, draw their supply from the ground water. The amount of water which a well will afford within a given time depends on a number of conditions, the principal one of which is the nature of the pervious bed. Thoroughly saturated gravels and coarse sands deliver water faster than fine sand. As water is pumped from the well the surface of the water lowers, but this is slow and hardly perceptible in cases where the materials are coarse and there is an abundance of water. It is desirable, therefore, to find water-bearing beds of coarse sand or gravel, and material of this sort prevails at most localities in this region. The water from the Cretaceous formations is generally bad, except that from the Dakota sandstone, and even this is often charged with mineral matter. The Tertiary and Quaternary deposits generally yield a suitable supply of water of good quality. Wells, except the deeper tubulars, vary in depth from a few feet to between 200 and 300 feet, and in diameter from 2 inches to several feet. They are cased with wood, brick, tile, cement, stone, and iron pipe, the first named being mostly used, and the last named being used in driven wells. Wells are dug, drilled, bored, and driven. The water level in most shallow wells is affected somewhat by weather changes. Those on the Missouri bottom, when near the river, seem to fluctuate somewhat with the flood and low-water stages of the river.

ARTESIAN WELLS.

Artesian conditions.—The entire area treated in this report is underlain by the water-bearing Dakota sandstone, which yields artesian wells in many districts. Part of this water comes to the surface in numerous springs in Dixon and Dakota counties, but to the west it lies at depths gradually increasing to 1,500 feet or more. The source of this water is in the Black Hills and the Rocky Mountains, where the Dakota and associated sandstones are extensively exposed. Thence this sandstone dips eastward beneath later Cretaceous clays, but it comes to the surface along Big Sioux River, in Iowa, and also along Missouri River below Ponca, Nebr. The sandstone is porous, and also thick enough to receive and carry large amounts of water. The supply is gathered in the mountain areas and flows very slowly through the sandstone to the lower regions east, where (as, for instance, along the valleys and lower lands of Nebraska and South Dakota) part of it comes to the surface through springs and artesian wells. An important factor is the thick mass of impervious clay and shale overlying the water horizon and preventing its escape in the wide area of plains between the mountains and the Missouri. Such beds overlie the Dakota sandstone as far east as Ionia, Nebr., in the river valley and somewhat farther on the highlands. Talus slopes, glacial clays, and fine sands aid greatly in checking the free escape of water in the eastern outcropping area. Owing to the high altitude of the gathering grounds on the mountain slopes, 4,000 to 5,000 feet, and the low altitude of the region east, the water is under such pressure or head that it flows slowly eastward through the porous sandstone.

The Carboniferous beds which underlie northeastern Nebraska carry artesian water, but at a considerable depth. This horizon was reached in wells at Sioux City, Iowa, and at Ponca, Nebr.

The sandstone of the Carlile formation carries artesian water and yields the weak " pencil " flow or " straw " flow of Knox and Cedar counties. Some of the artesian springs farther up the river may issue from this horizon.

Chemical composition of artesian water.—The chemical composition of artesian water seems to vary somewhat with the different flows and localities. The most common mineral compounds present are sulphates of soda, lime, and magnesia, chloride of sodium, and iron, all usually in small amount. There is only a trace of organic impurity.

The following analysis of water from the small school well, Santee, Nebr., was made by Prof. Robert O. Riggs:

Analysis of water of small school well, Santee, Nebr.

	Parts per million.
Silica (SiO_2)	9
Aluminum (Al)	2.1
Calcium (Ca)	242
Magnesium (Mg)	48
Sodium (Na)	87
Potassium (K)	29
Sulphate radicle (SO_4)	733
Carbonate radicle (CO_3)	84
Bicarbonate radicle (HCO_3)	68
Chlorine (Cl)	55
	1,357
Total solids	1,360

The iron was not determined but there is more of it in the water of this well than in that of the large school well.

Pressure.—Owing to the elevated source of waters in the Dakota sandstone, these would be under great pressure under the lowlands east were it not for the leakage in the outcrop area which causes the "head" to gradually decrease from west to east. The pressure or head is of great practical importance, for it determines the height to which the water will rise, and consequently the area within which artesian flows are to be expected. This area, deduced from observed pressures, is shown in Pl. IX (in pocket). As the Dakota is composed of alternating beds of sandstone and clay which often are distinct, there are different flows, called "first," "second," "third," etc., which have different pressures or heads, usually greatest in the lowest. This is because there is freer leakage from the upper than from the lower sandstone horizon.

In northeastern Dixon County there is no pressure in the upper sandstone beds of the Dakota formation and only enough in the lower beds to raise water a few feet above the level of Missouri River. Farther west, in northwestern Dixon County and northern Cedar County, the pressure is so small in the upper beds that the flow is not strong, but at lower levels a greater pressure is found.

At Niobrara the pressure is strong enough to force water about 210 feet above the mouth of the Mill well, or to an altitude of 1,450 feet. As above explained, the pressure and head increase from east to west, and if it were not for the fact that the rise of the country is usually more rapid in that direction than the general increase gradient of the water head, artesian water could be obtained over a much greater area. As it is flowing wells are obtainable only in the valleys. At Lynch, at an altitude of about 1,392 feet, there is a closed pressure of 85 pounds to the square inch. Allowing a head per pound of 2⅓ feet (the height of a 1-inch column of water weighing one pound), the water would rise in a pipe 198 feet above the mouth of the well, or to an altitude of over 1,590 feet. As the well is 923 feet deep there is sufficient pressure to raise water in all 1,121 feet. Dividing 1,121 by 2⅓ we find that the pressure at the bottom of the well is 480½ pounds per square inch.

In the Rosebud Agency well farther northwest, in South Dakota, the artesian water raises to an altitude of 2,000 feet. Different wells in a given locality may show different pressures. The variations may be due to one or more of the following conditions: (1) Difference in the horizon of the flow, the pressure being greater with deeper flows; (2) escape of water outside of the casing; (3) leaks in the casing due to rust; (4) difference in altitude of mouths of wells; (5) choking of flows by sand or clay; (6) proximity of wells causing local interference and decrease below the average pressure; (7) short, loose, or broken casing permitting leakage from a lower sandstone into an upper one.

Temperature of artesian water.—In a given locality the temperature is highest in the deeper wells. There is a gradual decrease eastward from over 80° F. in the deep well at Lynch to 54° in one of the Ryan wells in the northern part of Dixon County. It has been observed that the shallow artesian wells with weak pressure have about the same temperature as springs.

Construction and care of wells.—It was noted that in many cases but little care had been taken in the selection of proper sites and in the construction of wells in northeastern Nebraska. Some wells have been drilled on land too high for a flow, even when a lower position would have been just as convenient to the owner. Some wells on moderately high lands, which did obtain feeble flows, have since ceased flowing. Wells should be carefully cased, and the casing should fit tightly into cap rock and permit no leakage. Below the cap rock perforated pipe should be used for a part of the distance at least to prevent sand choking the end of the casing. In too many instances there is not enough casing, and it is often so loose that water flows outside of it to the surface. It is best to use double casing. Water standing about the mouth of the well causes the pipe to rust badly, but this can easily be prevented by carefully piping and grading. One of the largest and most expensive wells in the area was lost by the rusting of pipes near the surface; in this case there was a pond of water about the well. In wells with double casing the old inner pipe can be drawn and replaced by a new one.

Large and expensive wells to be used for power should be put down by experienced well drillers who understand how to cut off the upper and weaker flows and produce a well with the greatest possible pressure. It has been found best to keep such wells closed when not in use. If properly cased and not running sand there is no danger of injuring the well by shutting off the flow, but it should be shut off gradually.

Diminution in pressure and supply.—It is believed that in some portions of the artesian area the pressure and volume of flow is diminishing, but reliable data bearing on this point are difficult to obtain. Many wells decrease in volume after flowing some time, but the change is often due to breaks in the pipe, leakage, and clogging by sand or iron rust. Sometimes the diminution is local and due to the large number of wells. It is claimed that the pressure in the first and second flows in the Dakota sandstone is decreasing in Cedar County; the first flow at present runs a 2-inch pipe half full, while formerly it ran a full pipe; the second flow, about 80 feet deeper than the first and having more pressure, shows but little change; the third flow, from 30 to 40 feet below the second, has changed very little, if any.

BLOWING WELLS.

Blowing wells are found at a number of places in Nebraska, especially in Jefferson County. They are also known as "breathing," "howling," and "weather" wells. They occur at several localities in southeastern Knox County and about Mineola, Holt County. The wells have a depth of from 125 to about 200 feet, passing through loess, sand, dry gravel, and sand into water gravel. In some cases there is only a slight movement of air into and out of the well, called "sucking" or inhalation and "blowing" or exhalation. Where the casing is tight above and the opening small a very audible noise may be produced. The movement of air, up or down, seems to depend on the barometric pressure. When the air is heavy during a high barometer the movement is inward, while when the air is light during a low barometer it is outward. Since the well and weather phenomena correlate so closely the wells are called weather wells, and the changes in atmospheric pressure are supposed to cause the "blowing." The dry gravel below forms a reservoir into and out of which air readily passes. While there is more or less air in all formations, that in the porous beds moves most freely. Naturally this reservoir of air is affected by pressure, and the well is an artificial connection between the atmosphere and the air in the porous beds below. Inhalation during very cold weather causes the pipes to freeze sometimes as far down as the water. As soon as a reverse movement begins the pipes thaw out rapidly.

Mr. Charles C. Cleveland, of Creighton, Nebr., furnishes the following description of his well:

> My well is 3 feet in diameter and 165 feet deep, dug through loess, 80 feet; sand and gravel, 65 feet; clay, 20 feet. From this clay a 2-inch hole was bored down to water gravel from which the water flowed 15 feet deep in the 3-foot hole. In this well there is at times a current of air moving in or out, although

during much of the time it is entirely still. When the weather moderates in winter or is getting warmer at any time the well blows, and the air hissing through the platform can be heard rods away. When the weather turns cold, the air is sucked in. This air must have come out of the dry gravel below the loess. The pump platform has to be made air-tight in winter to prevent pipes freezing to the bottom of the well. All deep wells in this vicinity are blowing wells.

POLLUTION OF WELL WATERS.

Water is rendered impure by the presence of mineral and organic matter. Some kinds of these may be present without affecting the desirableness of the water for drinking and domestic purposes, but most impurities either are, or are likely to become, injurious to the health. The water supply which comes principally from shallow wells and springs often become contaminated from the surface and is then a source of contagion. Many cases of typhoid fever have come from this cause. The site for a dug well should be selected with great care and should be as far as possible from barnyards, backhouses, etc. All surface drainage should be kept away. Placing a well on higher ground than the house and outbuildings is not always a safeguard, for the water level in a well is so low that in some cases there may be a direct underground seepage from a dangerous source of contamination. Wood curbing often fouls the water by rotting. Spring water may also become polluted if it flows from sands not well protected from surface contamination.

WATER RESOURCES BY COUNTIES.

NORTHERN PART OF HOLT COUNTY.

Topography.—The northern part of Holt County drains northeastward to Niobrara River. It is a thinly settled region of over 900 square miles, in which stock raising and dairying are the principal industrial pursuits, especially where the land is rough or sandy. There is considerable farming on the table-land just north of Stewart, Atkinson, and O'Neill. North of this table-land the slope to the Niobrara is quite perceptible, as there is a fall of 400 to 500 feet in from 15 to 25 miles. Tertiary sands form the broad surface slopes. A sand-hill area 5 to 8 miles wide, but with indefinite boundaries, lies just south of Niobrara River and extends across the northern part of the county. The surface sands and gravels here were derived in part from the Tertiary sands and in part from materials brought into the region by Niobrara River when it flowed at a higher level. Beneath the sandy formations the whole region is underlain by Pierre clay, which comes to the surface along the Niobrara and along the lower courses of the principal creeks, forming steep slopes.

The main stream is Niobrara River. Its principal tributaries in this county are the Redbird, Eagle, Big Sandy, and Beaver creeks, all of which head in the table-land and flow northeastward to the river. They are fed principally by springs and flow all the year, the run-off not being much affected by the average rain or by dry weather. The streams vary in length from about 15 to 30 miles, and the grade varies but is generally steep. The valleys are narrow and semicylindrical in form at the edge of the table-land, wider and more mature across the Tertiary slopes, and more deeply trenched in the outcrop zone of Pierre clay. The stream water is used principally for stock and to some extent for domestic purposes.

Water power.—None of the creeks have been gaged, but it is evident that they would afford much water power, and the conditions are such that power could be easily and cheaply developed. There are favorable places for inexpensive dams along all of the creeks, while on some of the principal creeks there are numerous power sites. At Turner, Mr. William Knollkemper has a dam (see Pl. VII, *B*, p. 18) 150 feet long and 8 to 10 feet high, constructed of brush, clay, and manure. The power is used to run a well-equipped flouring mill, with a capacity of 60 barrels a day, which has been in operation for twenty-five years. The dam cost but little, for it is simply a crude breakwater which diverts part of the stream into a mill race. For several years a mill was operated on the Big Sandy, near Badger, but it was recently moved to Butte, Boyd County. The dam and race have been somewhat improved and power will be transmitted to the mill at Butte, a distance of 7 miles.

The main drawback to the development of water power for mill purposes in the northern part of Holt County is in the lack of shipping facilities for mill products. However, cheap power could be developed and transmitted to railroad towns both north and south. This plan ought to prove feasible, as fuel for power is high priced.

Springs.—Springs from Tertiary and terrace sands and gravels lying on the impervious Pierre clay are numerous along all of the creeks. They afford a large supply of good drinking water, and are used for domestic purposes, stock water, and for irrigation when needed. About Ray they are found on many farms and occur numerously about Saratoga on a small tributary of Eagle Creek. Above Turner on sec. 26, T. 32, R. 11 W. the John Donlin Springs seep out of the sands. Little Sandy Creek heads at a large spring. Near Phoenix some heavy springs are used to irrigate a large orchard, and 5 miles west of Badger some strong springs are used for irrigation during dry years. The Mullehan Springs near Paddock are well known; the water comes out of sand and gravel above the Pierre clay, forming a small fall 35 feet high. In this vicinity there are several very strong springs, most of which are not used. Near the mouth of Eagle Creek springs supply large fish ponds and in dry seasons irrigate from 15 to 20 acres of orchard and garden. At another ranch 2 miles east the spring water, conducted by a ditch three-fourths mile long, is used for irrigation purposes. The springs of this county could be used to greater advantage than they are at present, for in most cases they are high on the slopes and might be piped to and through the houses, which are generally located in the valleys below. Also it seems probable that by boring or by tunneling the ground water at boggy places not far below the table-land could be tapped and caused to flow out as strong springs.

Shallow wells.—Since settlements usually begin along the streams or at springs, few wells were put down until the country back from the natural water supply began to be used, first for grazing and later for farming. In much of the higher area of the county sandy formations yield a suitable supply of water, usually soft. At a few places, as north of Middle Branch, the water is in fine sand and is difficult to strain. There are several blowing wells in the vicinity of Mineola.

The following table will serve to show the different well-water conditions:

Representative wells of northern Holt County, Nebr.

Owner.	Location.	Depth.	Diameter.	Depth of water.	Remarks.
		Feet.	*Inches.*	*Feet.*	
O'Neill	O'Neill	1.400	(a)	1,360	Some bad water. Failure. Cost $3,000.
J. M. Packard	Sec. 12, T. 29 N., R. 9 W.	160	2	....	Sand all the way down, on high ground. Uses Cook strainer.
E. H. Lees	Sec. 28, T. 31, R. 10 W.	60	8	10	On high ground. Through 57 feet of sand into gravel.
H. R. Henry	Sec. 22, T. 30, R. 10 W.	68	10	9	Through sand and gravel to coarse gravel. Blowing well. High ground.
George Tomlison	Sec. 25, T. 31, R. 10 W.	76	8	12	High ground.
A. B. Powell	Sec. 3, T. 31, R. 10 W.	80	8	8 or 9	Do.
A. L. Wilcox	Sec. 18, T. 31, R. 12 W.	16	42	4 or 5	In valley.
Mr. McGowen	Sec. 24, T. 31, R. 12 W.	365	....	....	Through sand and gravel 15 feet into Pierre clay. On Red Bird divide.
Henry Lasher	Sec. 24, T. 31, R. 12 W.	120	8	14	Log: Clay and sand, 25 feet; clay, 20 feet; hard sandy layer, 1 foot; soft decomposed layer; sand.
J. J. Schwetzer	Sec. 36, T. 31, R. 12 W.	8	36	....	Dug well. In valley.
A. Dobson	Sec. 12, T. 33, R. 12 W.	20	....	12	In valley.
J. F. Green	Sec. 9, T. 33, R. 14 W.	18	12	8	Water in pure white sand just above Pierre clay.
Frank Sanders	Sec. 12, T. 33, R. 15 W.	20	10	10	Abundant supply.
William Dusten	Sec. 22, T. 33, R. 15 W.	90	12	....	
Winslow Bros	Sec. 14 T. 33, R. 14 W.	28	5	10	Easily lowered Through soil, sand, gravel.
A. W. Sexton	Sec. 33, T. 34, R. 14 W.	26	12	13	Easily lowered.

[a] Reduced three times; 2 inches at bottom.

Artesian water.—There are no deep artesian wells in this county, but many shallow flowing wells are found in the southern townships south of the area treated in this report.

The deep flow reached at a depth of 923 feet in the new well at Lynch, Boyd County, should, if tapped at Whiting bridge, have pressure sufficient to raise the water 75 feet or more above the river. According to barometric readings this would lack about 45 or 50 feet of reaching the river level at the Badger bridge. But since there is a gradual increase in pressure to the west, it is quite probable that a fair flow could be obtained at Badger at a depth of somewhat over 1,100 feet, and on the same basis it appears likely that the water would rise to the river level as far west as the mouth of the Keyapaha River and probably farther.

BOYD COUNTY.

The water conditions in Boyd County present considerable variety, owing to the diversity of the geologic formations. These comprise surface alluvial deposits, Tertiary sands, Pierre clay, and the Niobrara chalk rock.

Streams.—Missouri River receives several unimportant tributaries in the northeastern part of the county, draining an area of approximately 50 square miles of hilly country. The Niobrara flows with steep grade along the southern border of the county, draining a narrow district of approximately 125 square miles and a much larger area in Holt County. This water is used for stock and to some extent for domestic purposes, especially where a suitable supply can not be had from springs and wells. Keyapaha River, a tributary of the Niobrara, flows through a grazing country and is an important source of stock water. The conditions along this stream are favorable for small power sites. Ponca Creek, though having but a weak flow, drains more than half of the county. Its lower course is quickly affected by storm water, owing to extensive slopes of gumbo, or Pierre clay. It heads in broad, shallow sloughs in Gregory County, S. Dak., and in the high lands of Boyd County receives small amounts of ground water and a limited supply from direct run-off. Between Spencer and Butte there are successive terraces at rather regular intervals along the valley, which afford a good supply of spring and well water. Here many of the weak tributaries begin in elliptical holes and ponds in shallow sloughs. Ponca Creek affords good stock water. It has been used successfully as a source of mill power.

Springs.—The source of spring water here, as in Holt County, is the ground water in the Tertiary and terrace sands and gravels. Springs occur in large numbers; for example, on the SE. ¼ sec. 8, T. 34, R. 16 W., there are 25 springs, and on sec. 5, adjoining, a shallow cut developed a supply of water that flowed a distance of 120 rods.

The supply of water for Spencer is obtained from springs which come out of terrace sands and gravel three-fourths of a mile northwest of the town. The water is collected in a reservoir at the highest possible level and then pumped to a standpipe. Spring water is piped into a house in Lynch. All along Ponca Creek above Bristow springs issue from sand just above clay, and similar conditions exist along all of the principal streams of the county, especially the Keyapaha in the region of Twin Buttes.

Shallow wells.—The well-water supply of Boyd County has been reported as limited and bad, but, while it is true that some farmers have to haul water and that certain small towns have a poor supply, such cases are exceptional. Much alkali water is found in Pierre clay areas, but a large amount of soft water is obtained from Tertiary sand. Many of the gravels yield hard water, and the supply from the chalk rock seldom is satisfactory. Since the central and eastern parts of the county present a variety of surface formations, there are frequent differences in the quality of the underground water. In the area of Pierre shale, where the soil often is satisfactory for crop raising, the water is nearly always bad, but ordinarily it is practicable to locate the farm house on some other formation which will yield good well water. In locating wells it is advisable to prospect in sandy soil with small augers, and in sinking it is best to stop as soon as gumbo is reached, unless a cemented reservoir is to be constructed, for the alkali is dissolved from the clay by the water while it stands in the well. It has been observed that heavy pumping improves the quality of water in wells sunk through sand into the clay. Dry wells are not numerous and probably they occur only where the surface of the impervious clay rises above the ground-water level. Ordinarily such areas are of small extent, and trial borings will indicate their limits.

At Butte good and bad waters occur within a few rods. The water-bearing sands lie in depressions and yield a suitable and an abundant supply. In intervening areas the wells extend into gumbo and yield scanty supplies of poor water. If necessary an abundance of desirable water can be piped from wells near the buttes just south of town. At Monowi the wells are not favorably located, and the result is unsatisfactory. The supply at Gross is usually good.

Representative shallow wells of Boyd County, Nebr.

Owner.	Location.	Depth.	Diameter.	Depth of water.	Quality.	Remarks.
		Feet.	*Inches.*	*Feet.*		
Hamilton place	Sec. 36, T. 32, N. R. 9 W	22	20	9	Soft	
Chris Johnson	Sec. 24, T. 32, R. 10	25	18	5	Bad	Limited supply. Soil, sand, gravel, Pierre clay.
Charles W. Orr	Sec. 33, T. 34, R. 10	15	36	4	Hard, good	
C. C. Irwin	Sec. 14, T. 33, R. 10	24	16	9	do	Soil, sand, gravel.
J. C. Hoffman	Sec. 14, T. 33, R. 10	21	36	3	do	Sand and gravel.
Hubert Van Pelt	Sec. 14, T. 33, R. 10	22	12	5	do	Soil, sand, gravel. Limited supply.
B. Baker	Sec. 2, T. 32, R. 10	12	60	6	Hard, fair	Soil, weathered Pierre clay.
Albert Gillman	Sec. 2, T. 33, R. 10	22	36	10	Hard, poor	Soil, sand, weathered Pierre clay. Limited supply.
F. P. Mark	Sec. 34, T. 34, R. 10	24	24	16	Medium hard, good	Sandy loam, clay, sand.
John W. Orr	Sec. 21, T. 34, R. 10	30	24	8	do	Soil, clay, native lime, sand, and gravel.
C. A. Dean	Sec. 19, T. 34, R. 10	89	18	10	do	Soil, sand, clay, sand.
F. M. Stumbo	Sec. 20, T. 34, R. 10	44	28	16	Soft good	Water in 16 feet of gravel under 24 feet of Tertiary marl.
P. Carroll	Sec. 29, T. 34, R. 10	22	12	12	Hard, good	
Joseph Crowe	Sec. 22, T. 34, R. 10	16	36	4½	Soft, fair	
I. Jonason	Sec. 25, T. 33, R. 11	48	36	3½	Soft, good	Water in sand.
W. T. Reshaw	Sec. 18, T. 33, R. 11	66	24	7	Medium hard	Very cold water in thin bed of sand.
A. Fulckrod	Sec. 9, T. 33, R. 11	11	36	6	Poor	
Wm. Seeley	Sec. 18, T. 33, R. 11	66	24	6	Alkaline, bad	Soil, Pierre clay.
Martin Laugon	Sec. 19, T. 33, R. 11	36	4	13	Medium hard, fair	
Henry Wagoner	Sec. 28, T. 34, R. 11	33	36	10	Soft, good	
W. J. Everett	Sec. 2, T. 35, R. 11	32	24	6	Soft	Water in gravel under 21 feet of sand.
W. T. Reshaw	Sec. 35, T. 33, R. 12	30	16	15	Medium hard, bad	Poor water; not used; in Pierre.
L. S. Anger	Sec. 34, T. 34, R. 12	45	12	4	Soft	Soil, sand and gravel.
M. Coleman	SE. ¼ sec. 35, T. 33, R. 12	24	36	12	do	Soil, sand, and thick white chalk.
W. E. Kloke	NE. ¼ sec. 35, T. 33, R. 12	21	12	9	do	Soil, hard-pan soil, putty rock 8-9 inches; gravel, 1 foot; quicksand, 6 feet.
I. N. Morrison	NW. ¼ sec. 10, T. 34, R. 12	13	36	8	Medium	Soil and sand.
J. D. Schmidt	Sec. 22, T. 33, R. 12	32	12	8	Soft	Soil, sand, and gravel. Just to Pierre.
S. C. Claucus	Sec. 6, T. 33, R. 12	18	13	10	do	Soil, sand, and gravel.
W. S. Eaton	SE. ¼ sec. 30, T. 34, R. 12	41	26	6	do	Black soil, 3-4 feet; sand and gravel, 5-6 feet; clear sand, quicksand.
John Lampman	NW. ¼ sec. 31, T. 34, R. 12	32	38	8½	Hard	Soil, sand, white chalky clay.
O. R. Carmidrall	SW. ¼ sec. 31, T. 34, R. 13	75	15	15	do	Clay, rest magnesia. Some gravel in bottom.
A. D. Prattyman	NW. ¼ sec. 6, T. 33, R. 13	70	36	12	Soft	Soil and clay subsoil (light). Did not reach soapstone.
J. P. Ross	Sec. 24, T. 33, R. 13	36	10	9	Hard	Soil, sand, and gravel. Water in gravel.
C. E. Whittig	NW. ¼ sec. 15, T. 34, R. 13	32	16	10	do	Clay, gravel, and quicksand.
Elrich Windmyer	SE. ¼ sec. 21, T. 34, R. 13	50	18	25	Soft	Soil, light-colored, sandy clay. Did not reach soapstone.
John Webber	Sec. 36, T. 33, R. 13	10	48	5	do	Soil and sand.
J. D. Garmley	NW. ¼ sec. 29, T. 34, R. 13	33	36	10	do	Soil, 5 feet; sand, 12 feet; magnesian clay, 20 feet; sand and gravel.
J. Gamley	Sec. 25, T. 34, R. 14	43	48	16	do	Soil and loam, 10 feet; clay, 30 feet; sand and gravel.
G. S. Wright	NE. ¼ sec. 21, T. 34, R. 14	32	22	16	Medium hard	Soil, clay, subsoil, sand.
Ed McKemper	Sec. 30, T. 35, R. 16	125	12	15	Soft	Water in 14 feet; sand and gravel under 110 feet of Tertiary marls and sands.
Dwight E. Brown	SE. ¼ sec. 8, T. 34, R. 16	33	16	10	do	Soil and clay.
Jacob Heimerdinger	SW. ¼ sec. 11, T. 34, R. 16	15	48	10	Hard, good	Clay, 4 feet; balance in a flinty rock.

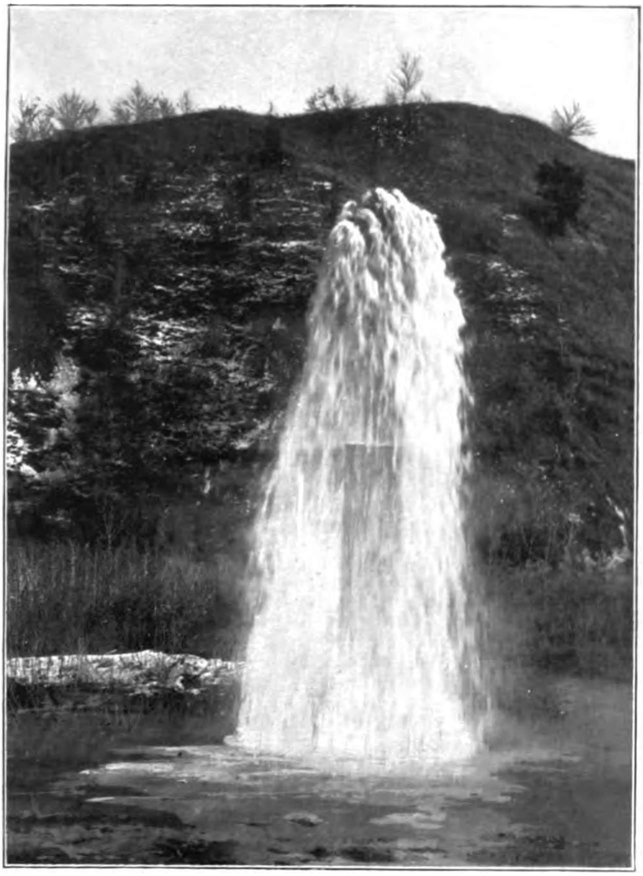
Artesian wells.—All of Boyd County is underlain by Dakota sandstone containing artesian water, but only a limited area is low enough for surface flows. Strong wells can be obtained along the Missouri bottom and along the Ponca Valley at least as far west as Spencer. The heavy pressure in the deep well recently finished at Lynch demonstrates that there is a deeper and stronger flow there, and probably that artesian wells can be had farther up Ponca Creek and Niobrara River than was formerly supposed. A deep flow was reached at Lynch, which has sufficient pressure to raise water to an altitude of 1,590 feet. This indicates that a surface flow can be obtained in the valley below Spencer, at a depth of about 1,065 feet. If the pressure increases westward across Boyd County a flow may be had in the valley below Anoka at a depth of about 1,170 feet, and as far west along the Niobrara bottom as the Badger Bridge and probably farther. Wells far to the west are more expensive to bore on account of increased depth and will afford little water power.

The wells at Lynch throw much light on the underground conditions. In the old well, completed in 1900, it is reported that at the top there were 260 feet, mostly "soapstone," 40 feet of Niobrara chalk rock at the base of the Niobrara formation, 275 feet of "soapstone" with some hard layers, 25 feet of hard rock and "sandstone" (presumably Greenhorn limestone), 20 feet of soapstone and clay, 50 feet of slate with coaly layers, 4 feet of so-called coal, 38 feet of sandstone, 30 feet of hard clay and sandstone, and 18 feet of porous sandstone in which the flow began. Other flows appeared in sandstones below until, at 797 feet, the flow was so strong that work was discontinued. The flow was 465 gallons a minute, pressure 52 pounds, temperature 79½° F., and diameter 6 to 4½ inches. In the new well bored in 1903 a pressure of 85 pounds is reported and a yield of 3,100 gallons a minute. The large flow in the new well is somewhat spasmodic in pressure and it has also thrown out considerable sand. It is to be used for mill power. The first flow was at 740 feet and the third at 875 feet; the temperature is 90°, and the diameter is 10 inches to 350 feet and 8 inches below. This well is shown in Pl. X.

Section of the new artesian well at Lynch, Boyd County, Nebr.

	Feet.
Sand and gravel	0–18
Pierre clay (called soapstone)	18–105
Niobrara chalk rock, sandy and hard below	105–300
Carlile clays, with some beds of pyrites	300–588
Greenhorn limestone	588–610
Graneros clays and shales	610–700
Dakota sandstone and clay, alternating. Four or five different flows reported	700–923

Total depth 923 feet. Altitude of mouth, 1,392 feet.



SECOND ARTESIAN WELL AT LYNCH, NEBR.

Analyses of waters of artesian wells at Lynch, Nebr.[a]

[Parts per million.]

	8-inch or new well.	4-inch or old well.
Combined water and organic matter	233	232
Silica (SiO_2)	56	16
Iron and alumina (Fe_2O_3 and Al_2O_3)	10	2.8
Calcium (Ca)	251	255
Magnesium (Mg)	39	57
Sodium (Na)	46	52
Potassium (K)	12	15
Sulphate radicle (SO_4)	682	667
Carbonate radicle (CO_3)	75	67
Chlorine (Cl)	74	61
Total solids	1,474	144

[a] S. Avery and A. Jacobsen, analysts.

A well is now (1905) being drilled on sec. 33, T. 34, R. 11, near Rosedale, but the drill is fast at a depth of 793 feet. If boring is continued, a good well may be obtained at a depth of 1,100 to 1,200 feet. The first mill well at Lynch was three years in boring. The following altitudes, obtained from the Chicago and Northwestern Railway and by the use of an aneroid barometer, may be of value in considering the depth and head of the artesian waters:

Altitudes on line of Chicago and Northwestern Railway.

	Feet.
Monowi[a]	1,322½
Lynch[a]	1,400½
Spencer[a]	1,541½
Anoka[a]	1,638½
Fairfax, S. Dak.[a]	1,932½
Niobrara River at Whiting Bridge	1,502
Niobrara River at Badger Bridge	1,635
Missouri River at Greenwood	1,229
Missouri River at Fort Randall	1,240
Town of Spencer	1,637
Town of Butte	1,795

KNOX COUNTY.

Loess, varying in thickness from a few feet to over 100 feet, forms the surface over most of Knox County, its continuity being interrupted by a sandy area west of Verdigris Creek, by a clayey region beyond the Niobrara, by sandy sections near Santee, and by places where deeper valleys cut through to underlying formations. The northern and central parts of the county are somewhat hilly, and lower than the more level regions to the south and southeast. There is considerable bottom land along the Missouri and the Niobrara. The chalk rock so prominently exposed along the Missouri extends southward under the Pierre, Tertiary, Glacial, and loess deposits.

---

[a] Base of rail at station.

In much of the county the Pierre clay and Niobrara chalk rock, which usually afford an inferior supply of water, are deeply buried by other formations and are not reached in ordinary wells. Except for an area of about 60 square miles draining south to Elkhorn River, the general slope and drainage is northward to the Missouri.

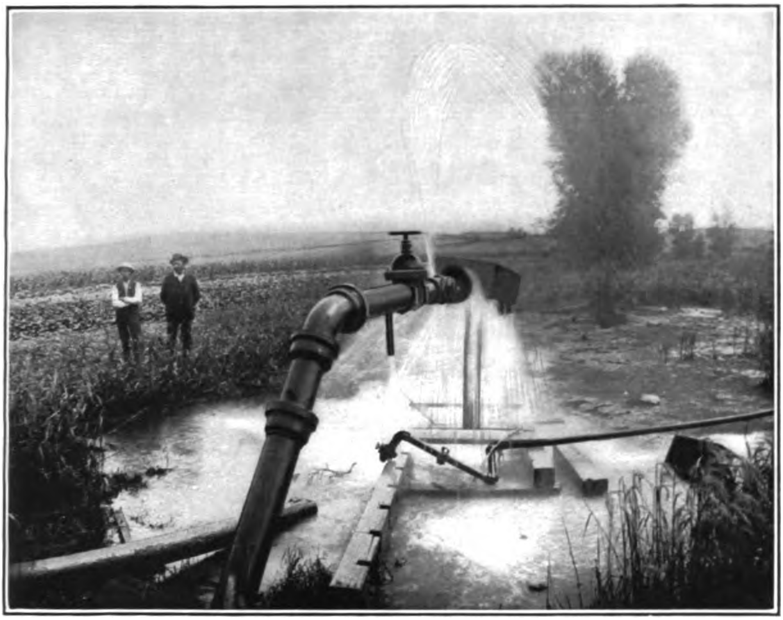
Streams and water power.—The Missouri is the most important stream; it flows along the northern margin of the county and is often the source of local water supply. The Niobrara River receives 7 tributaries of some importance from the south, but practically none from the north. Verdigris Creek, with a drainage basin of about 250 square miles, is one of the best water-power streams in northern Nebraska, gaging about 105 second-feet and flowing throughout the year. A mill is successfully run by water power from this stream at the town of Verdigre; the dam is constructed of greenish quartzite obtained 6 or 7 miles southwest. Several other good power sites exist between Verdigre and Niobrara River.

Bazile Creek closely resembles the Verdigris in character, but has a drainage basin in the center of the county, of about 400 square miles in area. Much of the power here is not favorably located with respect to railroads, but it might be transmitted to Creighton, Bloomfield, Winnetoon, and other towns. There are two well-constructed dams along the creek, one at the Bazile mill and the other at the lower Bazile mill (see Pl. XI, *B*). Each dam has a fall of about 12 feet and is made of greenish quartzite and each supplies water for 60-barrel flouring mill. Farther downstream numerous favorable power sites could be located.

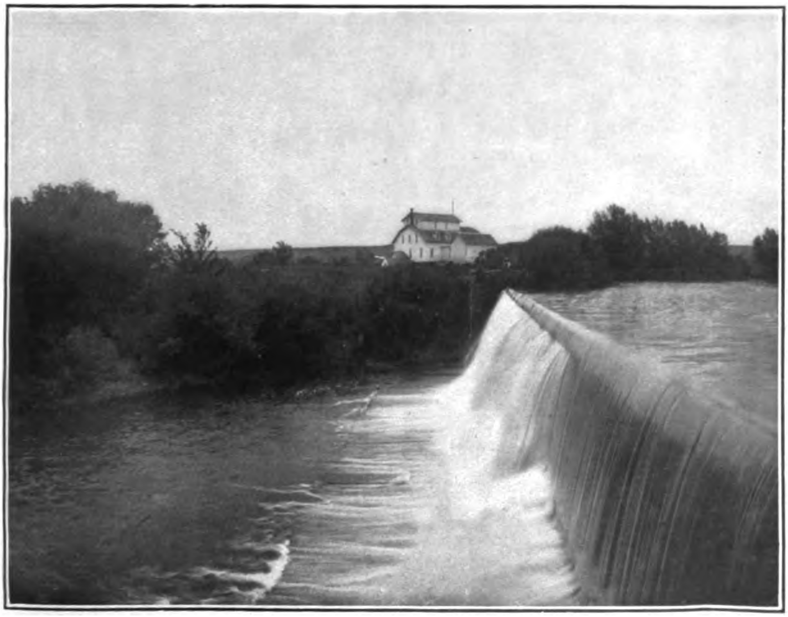
Frankforter Creek, frequently called Weigand Creek, in the northeastern part of the county, is too weak for power, especially during the drier months.

Springs.—The rainfall accumulates as ground water in the loess and sand and gravel deposits, and from these springs issue, especially at the contact with impervious beds. Many flow from the outcropping edge of the top of the Pierre clay, which extends along the sides of the valley slopes. Talus from later formations often covers the clay more or less in the outcrops and sometimes carries the spring water to lower levels. In some parts of the county the upper surface of the clay is very uneven as a result of erosion.

As in adjacent counties the number of springs is very great, practically every little ravine along the Niobrara, Verdigris, and Bazile valleys being fed by a spring, large or small. Only a few can be noted: Springs just southwest and northwest of Verdigre could be piped to furnish an abundance of water for the town. The La Mont Springs, about 2 miles south of Niobrara, are quite strong. A spring at the place of R. F. Stout, sec. 5, T. 30, R. 5 W., south of Center, is



A. OLD WELL AT SANTEE AGENCY, NEBR.



B. LOWER DAM ON BAZILE CREEK, KNOX COUNTY, NEBR. BUILT OF QUARTZITE.

piped some 350 yards to a hydrant at the house; the water, temperature 55½° F., issues from the base of coarse sand at the clay contact, at an altitude of about 1,525 feet, or 35 feet above the hydrant. A notably heavy spring is located 1½ miles southeast of Center. A small spring near the creek at the lower Bazile mill yields a good quality of drinking water; the flow is 7 gallons per minute, and the temperature 54½°. Several springs are found along the Frankforter Creek; one at Weigand affords a good supply of water for a public watering place, stock, and house use.

Shallow wells.—North of Niobrara and in the Ponca basin the shallow-water conditions are very variable; the best supplies are obtained from irregular areas of sand and gravel on the divides and from the flood-plain deposits. In the southwestern part of the county water is derived from Tertiary sands in wells from 100 to 200 feet deep. In the central, southern, and eastern portions good water is obtained in gravel, which often lies 175 feet deep on high ridges and table lands, and 20 to 35 feet in the old northwest-southeast valley extending from Verdigris Creek past Winnetoon and Creighton to the southeast. At a few places Tertiary sands rise above the gravel beds and afford a supply at less depths. Many blowing wells are found in Tps. 29 and 30, Rs. 2, 3, and 4.

The Pierre clay has not been reached in wells over 200 feet deep on the high lands south of Bloomfield, which indicates a great thickness of post-Cretaceous formations, many of them water-bearing. Over much of the eastern half of the county two gravel beds, separated by clay and sand, are encountered, except where they have been removed by erosion or where Tertiary sands rise above them.

In this county, as elsewhere, the water derived from wells extending into the Pierre clay and the Niobrara chalk rock usually contains much alkali, unless the beds have lost their soluble matter by leaching. Usually, not far from places underlain by these formations, good water may be obtained from alluvial or other sands.

Artesian wells.—Large supplies of artesian waters are available in all of the lower lands of the county, and in many places the conditions are favorable for high-pressure wells. The mill well at Niobrara, used so successfully for power, indicates that such wells might be obtained at many points on the Missouri, Niobrara, and Ponca bottoms. With little doubt one or more stronger flows can be had at a slightly greater depth, and an attempt is now being made at the Niobrara mill to reach one of these; the last report (1905) indicates slow progress in the drilling and a depth of 500 feet.

Representative shallow wells of Knox County, Nebr.

Owner.	Location.	Depth.	Diameter.	Depth of water.	Quality.	Remarks.
		Feet.	*Inches.*	*Feet.*		
Charles Cleveland	Sec. 28, T. 29 N., R. 4 W	186	4	36		Clay, 80 feet; gravel and sand, 65 feet; clay, 40 feet; gravel, 1 foot.
Jack L. Burt	Sec. 23, T. 29, R. 4	185	3	4	Soft	Yellow clay, 80 feet; sand, 60 feet; dry quicksand, 23 feet; dry gravel, 13 feet; hard pan, 4 feet; gravel, 4 feet.
D. C. Billeck	Sec. 26, T. 29, R. 4	182	2	10		Loess, 120 feet; sand, 18 feet; dry gravel, 24 feet; yellow clay, 8 feet; water gravel, 8 feet.
W. H. Wort	Sec. 26, T. 29, R. 5	40	12	10	Soft	25 to 28 feet sandy loam; sand, quicksand, gravel.
(In town)	Sec. 3, T. 30, R. 3	20	2	4		
Colin Valentine	Sec. 11, T. 30, R. 3	40	30	32	Soft	
Peter Ward	Sec. 1, T. 30, R. 4	126		2	do	Blue clay—some sand and gravel.
John Roberts	Sec. 3, T. 30, R. 4	90		Dry.		15 feet of black soil and rest mostly sand; coarse gravel in bottom.
John Tucker	Sec. 3, T. 30, R. 4	137			Hard	Black soil and sand with some clay.
John Roberts	Sec. 4, T. 30, R. 4	169		Varies.	do	50 feet black soil and rest dry sand; water easily lowered, but quite steady supply.
Louis Eggert	Sec. 8, T. 30, R. 4	102		2	do	Black soil on top, sand and gravel below.
Charles Ward	Sec. 9, T. 30 R. 4	140		12	do	Sand and gravel, little clay; water supply not steady; easily lowered at times.
I. Ellingson	Sec. 4, T. 30, R. 5	16		9		Sand and gravel; well in bottom above creek.
W. D. Patton	Sec. 35, T. 31, R. 3	14	3×4	3		
J. B. Crockett	NE. ¼ sec. 21, T. 31, R. 4	57		15	Hard	Soil, bluish clay, gravel and water. Blowing well.
Frank Hajek	Sec. 8, T. 31, R. 5	30	16	6	Soft	Soil, sand to soapstone.
Frank Jelenek	Sec. 5, T. 31, R. 5 (in town)	17	12	3	do	Soil, sand and water in gravel.
F. P. Krolop	NW. ¼ sec 12, T. 32, R. 8	18	18	10	Medium	Soil, sand, 2 feet; gravel, 2 feet; soapstone rest of distance.
Chris. Johnson	Sec. 28, T. 32, R. 8	8	36	4	do	Soil, 4 feet; sand, sand and gravel.
J. H. Rothwell	Sec. 25, T. 32, R. 8	35	1½	10	Hard	Soil; reddish clay, 25 feet; gravel.
M. Thompson	Sec. 18, T. 32, R. 6	21	2	10	Soft	Soil and sand. In Niobrara Valley.
J. A. Lindsan	Sec. 16, T. 32, R. 6	14	2	3	do	Black soil, 5 feet; sand, 9 feet.
L. Weigand	Sec. 1, T. 32, R. 3	24	24	10	do	Soil, clay, then water.
C. H. Sawyer	NE. ¼ sec. 7, T. 32, R. 3	40	36	9	Medium	Soil, loess, 35; sand and gravel with water.
Frank Weigand	NE. ¼ sec. 10, T. 32, R. 3	42	24	8	do	Soil, loess, 6; sand and gravel.
Chas. Jancore	Sec. 7, T. 32, R. 3	125	24			
James Renner	W. ½ sec. 23, T. 32, R. 3	24	36	15	Hard	Soil, sand and gravel. In small valley.
School	Sec. 13, T. 33, R. 5	80		6	Alkaline	6 feet into chalk rock.
Charles Jacocks	Sec. 11, T. 32, R. 3 W	130	36	5	Hard	Soil, loess and sand (?).
D. C. Cleveland	5½ miles east of Creighton					Sandy loess, 75; gravel, 80; fine sand, 10.

A new well is soon to be put down at the Santee Agency. The old well there, which has been used successfully for mill power, irrigation, fire protection, and general water supply, is now of little use (see Pl. XI, *A*), because the casing has rusted off 2 or 3 feet below ground. The large well at the school afforded clear water for about two weeks when finished, and the volume was at first over 2,000 gallons per minute. After a while it began throwing out sand and shale, and the flow ceased entirely a few times but was started again each time by cleaning. At present the pressure is 26½ pounds at the mouth of the well, which is 105 feet above Missouri River. In this well trouble was experienced with the casing at a depth of about 500 feet. The present water supply is thought to come principally from the first flow. Wells in the northeastern part of the county have decreased in pressure and flow, principally because they were not properly cased.

Attempts to get wells on high lands have failed because of the altitude, the pressure, though strong in the water-bearing beds below, not being sufficient to force the water to the height necessary.

Record of well at the packing house, Niobrara, on the Missouri bottom, sec. 8, T. 32, R. 6 W.

	Feet.
Soil and sand	0– 70
Niobrara chalk rock	70–200
Clays and shales with thin beds of iron pyrites (Carlile)	200–410
Limestone (Greenhorn)	410–442
Clay and shale (Graneros)	442–520
Dakota sandstone and clay	520–600

Record of small well at the school, Santee, Nebr., sec. 13, T. 33, R. 5 W.

[Mouth of well 143 feet above the Missouri River.]

	Feet.
Soil and sand	0 – 23
Pierre clay	23 – 35
Niobrara chalk rock	35 –240
Clay, shale, and thin beds of iron pyrites (Carlile)	240 –445½
Limestone (Greenhorn)	445½–502
Clay and shale (Graneros)	502 –600
Dakota sandstone	600 –604

Record of John Lytle well, sec. 19, T. 33, R. 2 W., Nebraska.

[Mouth about 70 feet above the Missouri River.]

	Feet.
Soil	0– 6
Niobrara chalk rock	6– 88
Clays and shales with hard beds (Carlile)	88–380
Limestone (Greenhorn)	380–400
Clay and some shale (Graneros)	400–490
Dakota sandstone and clay (second flow)	490–530

Artesian wells of Knox County, Nebr.

Name.	Location.	Diameter.	Depth.	When drilled.	Pressure when drilled.	Yield per minute.	Temperature.	Remarks.
		Inches.	*Feet.*		*Pounds.*	*Gallons.*	*F.°*	
Dan's well, Hiles ranch.	1½ miles east of Monowi, sec. 18, T. 33, R. 8 W.	3-2	770	1895			70	Pressure now 11 pounds, with leak. Third flow, 740 feet. Temperature varies.
O. Hegen	7 miles west of Niobrara, sec. 21, T. 32, R. 7 W.	2	500	1903				A surface flow is not expected. Depth given is for Aug. 15, 1903.
Mrs. John Havlicek	Near Verdigris, sec. 29, T. 31, R. 6. W.	2	770	1896	Formerly 34, now 11.	14 now	74½	
Niobrara mill well	Niobrara	8	656	1896	At first 95	1,900	68	Pressure July 14, 1903, 65 pounds when not entirely shut off. Pressure 120 pounds when closed 2 weeks in 1896.
Niobrara packing-house well.	do	2	600	1895	Reported 107	Was 280	66	Pressure weak now with leak; also yields about 35 gallons per minute.
Foreman ranch	4 miles east of Niobrara, sec. 12, T. 32, R. 6 W.	2	548	1903	82	240	65	Principal flow at 520 feet.
Large school well	Santee, sec. 13, T. 33, R. 5 W.	8	740	1899	55 when drilled, 26¾ now.	1,699 when drilled, 106.2 cubic feet now.	64	Mouth of well 105 feet above Missouri River.
Small school well	do	3	604	1885	Very weak		64½	This water is piped through houses.
Agency well	do	6	600		Weak		64	Not much used now. Leaks at break in pipe.
Herrick ranch well	2 miles west of Herrick, sec. 16, T. 33, R. 3 W.	2	400		Was strong, weak now.	8	62	Pipe badly rusted. On Missouri bottom.
Clark well (formerly Brown).	1½ miles northwest of Herrick, sec. 15, T. 33, R. 3 W.	2	400		Weak		61	On bottom land. Cased the second time.
T. C. Van Meter	Sec. 13, T. 33, R. 3 W	2	504	1892	Not strong	2	63	On high ground.
John Lytle	Sec. 19, T. 33, R. 2 W	2	550	1899		10	63½	About 70 feet above the Missouri River.
C. D. Buhrow	Sec. 20, T. 33, R. 2 W	6	650	1894	64 when drilled, ceased flowing this summer.	30 with big leak	62	Up Frankforter Creek. Diameter below 44 feet is 4½ inches.
Lytle ranch well	Sec. 17, T. 33, R. 2 W	2,3	400	1887	25½ with big leak	3	62½	Passed through 10 feet of bowlders at depth of 50 feet. Formerly had high pressure.
Mastin Mische	E. ½ sec. 20, T. 33, R. 2 W.	2	600		Weak now, was very strong.	6	62	About 70 feet above the Missouri River.
Kate Phelps well	SE. ¼ sec. 16, T. 33, R. 2 W.	1	400		11	3	62	On Missouri bottom.
John Mische	do	2	395		Weak	9	60	On Missouri bottom, near chalk bluff.
Chas. Mische, lot well.	Sec. 15, T. 33, R. 2 W	2	405		14 now, with leak		59½	Part way up chalk bluff.
A. P. Sage	Sec. 13, T. 33, R. 2 W	2	700		Does not flow			Used as a tubular well; 200 feet above river.
Chas. Mische	Sec. 15, T. 33, R. 2 W	2	425		14 now, with leak	9	61	Part way up chalk bluff.

CEDAR COUNTY.

The most extensive surface deposit in Cedar County is the loess, below which lie Quaternary and Tertiary sands, clay, and gravel. Of the Cretaceous formations only a few detached areas of Pierre clay occur, while Niobrara chalk rock underlies all of the county, either beneath later formations or at the surface. The other members of the Cretaceous exposed along the Missouri lie at lower levels beneath the chalk.

The surface of the county is for the most part gently rolling, with drainage to the northeast and southeast. The principal streams, aside from the Missouri, are Bow and West Bow creeks, which converge north of St. James. The southern and southeastern townships are drained by Logan Creek.

Springs.—The big springs near Coleridge were well known in the early history of the county as a watering place for immigrants. Curlew Springs, issuing from banks beneath the drift in a boggy slough, are also well known. The Frank Hochstein Spring on sec. 8, T. 32, R. 2, is perhaps the finest in the county. It is located at the foot of a loess-capped hill and the water boils up from a circular hole the depth of which has not been ascertained. The flow is between 400 and 500 gallons per minute, which, according to the owner, has not changed in thirty-eight years. The water deposits some iron and on that account is usually regarded as coming from the artesian supply. The temperature is only 50½°. The water is used for drinking, domestic and dairy purposes, and stock.

Shallow wells.—In this county there is usually an abundance of good water available in shallow wells, from Tertiary and Glacial sands and gravels. In some localities the wells extend into the chalk rock, which gives very hard water but contains less alkali than farther west, the formation appearing to be leached out in this county. Not many shallow wells are found along the Missouri bottom, the water supply there being derived from artesian wells.

The depth of common or shallow wells is controlled to a considerable degree by the topography. In the broad valleys water is obtained at a depth of a few feet, usually from 10 to 40, while on some of the intervening ridges and high lands the depth to it is considerably greater.

About Hartington the depths vary from about 15 to 35 feet and at Coleridge from 20 to 45 feet.

Representative shallow wells of Cedar County, Nebr.

Owner.	Location.	Depth.	Diameter.	Depth of water.	Quality.	Remarks.
		Feet.	*Inches.*	*Feet.*		
Chas. Clark	Sec. 21, T. 33 N., R. 1 W.	60	24	15	Hard	Soil, clay 20-30 feet; chalk rock.
James Marsh	Sec. 16, T. 33, R. 1 W	72	24	20	do	Good drinking; soil, clay; chalk rock.
Town well	Sec. 16, T. 33, R. 1 W	70	60	11	Medium	Soil to 12 feet; sand; soil; gravel with water.
H. Wubben	NE¼ sec. 23, T. 33, R. 1 E.	100	36		Hard	Soil; loess 30 feet; red chalk rock 20 feet; blue chalk 48 feet.
Carl Doeller	Sec. 35, T. 33, R. 1 E	50	48	2	do	Soil; loess 44 feet; chalk.
L. P. Lauretzen	Sec. 26, T. 32, R. 2 E	50	48	10	do	
Ernest Ferber	Sec. 1, T. 31, R. 2 E	36	2			Black dirt 3 feet; sand 22 feet; balance gravel.
W. H. Hight	Sec. 9, T. 29, R. 2 E	13	39	9	Medium.	Soil, gumbo; sand in bottom.
Ed Fiscus	Sec. 18, T. 29, R. 3 E	55	2½		Hard	Soil, silty; loess 51 feet; sand with water at bottom.
R. C. Chase	Sec. 34, T. 30, R. 3 E		30		do	Loess, sand, and gravel; is 60 feet below highest hills.

Artesian wells.—There are nearly 100 flowing artesian wells in Cedar County, all of which are either along or near the Missouri bottom. Their distribution is shown on Pl. IX (in pocket), and most of their features are given in the table, page 47. In addition to these there are many tubular wells on the highlands to the south, some of which flowed for a short time. The supply in these tubular wells comes from the artesian water in the Dakota sandstone and rises as high in these wells as it would in pipes at artesian wells on the Missouri bottom. Mr. Chamberlain, who drilled most of the wells in Cedar County, states that flowing wells can be had up West Bow Creek for 7 miles and up Bow Creek for 6 miles from the river. Beyond that distance they cease to flow.

This important resource should be protected by more careful casing of wells; all should be cased to the cap rock and kept under control at the surface. As it is there is an enormous loss by underground leakage and the waste of flows on the surface.

Record of artesian well at St. Helena, Nebr.

	Feet.
Chalky limestone	0- 25
Shale	25- 59
Dark blue clay	59-329
Shale	329-369
Black shale with hard layers and lignite 6 inches thick at 399 and 418 feet	369-418
Sand with flow, underlain by clay	418-466

Artesian wells of Cedar County, Nebr.

Owner.	Location.	Depth.	Diameter.	When drilled.	Pressure.	Yield per minute.	Temperature.	Remarks.
		Feet.	*Inches.*		*Pounds.*	*Gallons.*	*° F.*	
Frans Nelson	NW. ¼ sec. 17, T. 33, R. 1 W	500	1½		Weak		59	Soil; chalk to perhaps a little below the river clay, hard beds, and shale to sand rock.
Albert Miller	Sec. 18, T. 33, R. 1 W	648	3½		None			Water raised to within 56 feet of the surface about 200 feet above river.
D. Miller	NE. ¼ sec. 17, T. 33, R. 1 W	365	2	1898	15	26 at first	59½	Soil; sand 45 feet; no chalk; clay and shale for most of distance; thin cap rock with porous sand rock beneath. Flow at 337 feet.
John Nelson	SW. ¼ sec. 16, T. 33, R. 1 W	400	2	1883	Weak		59½	About 10 feet above river.
Do	SW. ¼ sec. 16, T. 33, R. 1 W	400	2		14	7 now	60	On Missouri bottom.
John Aten	Sec. 16, T. 33, R. 1 W	400	2	1896	9 now	7	58½	Do.
Eugene Saunders	SE. ¼ sec. 9, T. 33, R. 1 W	400	2	1896	8	7	58½	On Missouri bottom. Diameter reduced to 1 inch at top.
Joseph Holtzbauer	SE. ¼ sec. 10, T. 33, R. 1 W	400	2	1895	Strong	15	59	Soil and sand, 181 feet; clays, shale, and hard rock to water rock.
J. H. Coacher	SW. ¼ sec. 11, T. 33, R. 1 W	380	2					Rusted pipe. Used as tubular well.
John Nelson	Sec. 12, T. 33 R. 1 W	400	2		About 13	7	59½	Pressure was stronger.
L. Hoesing (Elkhoff well)	Sec. 30, T. 33, R. 1 W				None	Does not flow		On high ground. Tubular.
William Lackman	NE. ¼ sec. 27, T. 33 R. 1 W		2		do	do		Flowed for a time. Used as tubular well now.
Dave Nelson	Sec. 12, T. 33, R. 1 W	380	2	1897	Strong	44	60	
Albert Lee	Sec. 8, T. 33, R. 1 E	360	2	1896	Weak	78 when drilled; 52 now.	59½	Soil, 4 feet; quicksand, 20 feet; coarse sand and gravel, 30 feet. The rest of the way blue clay, with few layers of hard rock ranging from 3 inches to 3 feet in thickness.
C. B. Clark	NW. ¼ sec. 17, T. 33, R. 1 E	420	2		Good		69	
H. Yager	Sec. 16, T. 33, R. 1 E	360	2	1889	Weak	5½	58	On Missouri bottom.
M. U. Hoyt	SW. ¼ sec. 17, T. 33, R. 1 E	454	1½	1893	Fairly strong		58½	Is used for the house, barn, and three pastures.
Dave Nelson	NE. ¼ sec. 15, T. 33, R. 1 E		1½	1892	Weak	40		On Missouri bottom.
Mrs. Mary Bruns	Sec. 23, T. 33, R. 1 E	500	1½		do			
Joe Baehmer	Sec. 22, T. 33, R. 1 E	500	2	1890	Ceased to flow			First flow at 290 feet; second flow at 500 feet.
Do	Sec. 22, T. 33, R. 1 E	500	2	1896	Strong	15 to 20	62	
George Housman	Sec. 24, T. 33, R. 1 E	350	2		Strong; was 35	Full pipe	60	
A. Tielke	Sec. 25, T. 33, R. 1 E	630			Does not flow	Does not flow		Temperature warm.
H. Brunig	Sec. 25, T. 33, R. 1 E	602	2	1894		At first 25; does not flow now.		Clay, 200 feet; limestone, 25 feet; clay, 60 feet; hard rock, 40 feet.
John Cooper	Sec 25, T. 33, R. 1 E	520	2		Was strong	Does not flow now		Temperature was warmer than shallow well.
Kate Housman	Sec. 30, T. 33, R. 1 E	530	2	1901	19	30 at first	63	
John Statman	Sec. 30, T. 33, R. 1 E	600	2					Flowed for short time only. Now used as tubular well.
M. C. Smidt	Sec. 32, T. 33, R. 1 E		2		None	Ceased to flow		Soil, etc., 20 to 30 feet; chalk; clay over 100 feet; hard rock; clay and shale, 100 feet; sand and sandstone. Ran out of pipe at 300 feet. Water lifted at 120 feet, but did not flow out.

Artesian wells of Cedar County, Nebr.—Continued.

Owner.	Location.	Depth.	Diameter.	When drilled.	Pressure.	Yield per minute.	Temperature.	Remarks.
		Feet.	*Inches.*		*Pounds.*	*Gallons.*	°*F.*	
T. N. Jones	Sec. 34, T. 33 N., R. 2 E.	280	2	1893	Fairly strong	Pipe nearly full in horizontal position.	60	On Missouri bottom lands.
W. C. Jones	Sec. 28, T. 33, R. 2 E.	420	2	1893	Strong		60½	
Do	Sec. 29, T. 33, R. 2 E.	200	2	1896	do	Pipe nearly full	60½	
Do	Sec. 28, T. 33, R. 2 E.	300	2			Ceased flowing		
Frank Arens	Sec. 34, T. 32, R. 1 E.	535	3	1889		2		
B. Wubben	SW. ¼ sec. 5, T. 32, R. 2 E.	500	2		Weak	4	61	
Do	SW. ¼ sec. 5, T. 32, R. 2 E.	600	2, reduced to 1½ below.		At first 4	Weak at first, ceased flowing.		Passed through considerable chalk.
C. E. Klapping	Sec. 10, T. 32, R. 2 E.		2		Weak		60½	
Frank Wiesler	Sec. 9, T. 32, R. 2 E.		2		do	5	60	
Peter Hochstein	SW. ¼ sec. 8, T. 32, R. 2 E.	530	2	1888	do	2	60½	
Ernest Ferber	NE. ¼ sec. 10, T. 32, R. 2 E.	241	2	1886	do	Two 1½-inch pipes full.	60	
T. N. Jones	NE. ¼ sec. 10, T. 32, R. 2 E.	2	400	1890	Was 30, now 17 with leak.	Pipe full	60	First flow forced water 56 feet above the bottom, second flow strong, third stronger.
Jacob Keizer	SE. ¼ sec. 9, T. 32, R. 2 E.	2	500	1893	None now	Flows a little out of ditch 6 feet deep.		
August Hochstein	SW. ¼ sec. 10, T. 32, R. 2 E.	2	360	1894	Strong	Horizontal pipe nearly full.	59	In Bow Creek Valley.
F. Ashbre	NE. ¼ sec. 12, T. 32, R. 2 E.	2	300		do	11	59	
James Keegan	SE. ¼ sec. 14, T. 32, R. 2 E.	2	400		Weak	1	60	
John Hochstein	NW. ¼ sec. 15, T. 32, R. 2 E.	2	320		do	Size of finger flow.	59	Do.
W. D. Schulte	NE. ¼ sec. 23, T. 32, R. 2 E.	2	360	1887	30	60		
A. W. Jones	NE. ¼ sec. 11, T. 32, R. 2 E.	2	417	1896	10	Flows horizontal pipe (2 inches) half full.	58	
Do	Sec. 11, T. 32, R. 2 E.	2	300	1893	Could not gage	Flows 2-inch horizontal pipe.	58½	
Ferd Ashbre	NW. ¼ sec. 13, T. 32, R. 2 E.	2	400		Weak		59	
St. James Well	NW. ¼ sec. 24, T. 32, R. 2 E.	2	540		None	Does not flow now.		
Bert Thompson	NW. ¼ sec. 24, T. 32, R. 2 E.	2	300		Weak	2½	59	
F. Leise	SE. ¼ sec. 25, T. 32, R. 2 E.	2	340		do	2	58	
Do	Sec. 25, T. 32, R. 2 E.	2	400		Was weak	Flow ceased		
Peter Kugan, Ashmole Well.	NE. ¼ sec. 14, T. 32, R. 2 E.	2	520	1894	Strong	Flows horizontal pipe full.	62½	
Nels Anderson	Sec. 23, T. 32, R. 2 E.	2	400	1888	Weak	30		270 feet to water.
H. E. McKenzie	Sec. 24, T. 32, R. 2 E.	2	448	1894				At first flowed pipe full.
Jones-McKenzie	SE. ¼ sec. 7, T. 32, R. 3 E.	2	40		10	Flows a 2-inch pipe nearly full.	61	

Richard Brewer	SW. ¼ sec. 8, T. 32, R. 3 E.	2	400	1900	Nearly 4 now	Runs 2-inch horizontal pipe nearly full.	60½	Pressure varies with season. Strong when drilled. Decreased six months after.
Do.	NE. ¼ sec. 8, T. 32, R. 3 E.	2	300	1893	Weak	1½	58½	
H. Wiseman	SE. ¼ sec. 8, T. 32, R. 3 E.	(a)	280	1883	Could not determine.		58½	
T. W. Whitehouse	Sec. 9, T. 32, R. 3 E.	2						15 feet above river.
Riley Brewer	Sec. 9, T. 32, R. 3 E.	2	280			Runs ½ pipe full	59	
Mrs. L. Larson	SW. ¼ sec. 11, T. 32, R. 3 E.	2	280		None; was fairly strong.	None		Flow stopped in 1902, owing to rusted pipe.
S. Boyles	NE. ¼ sec. 15, T. 32, R. 3 E.	2	365		6	7	57	Well not well cared for. Overflows, forming a marshy pond.
Theodore Beste	SW. ¼ sec. 15, T. 32, R. 3 E.	2	310	1900	17	Good flow	60	
Do.	NE. ¼ sec. 15, T. 32, R. 3 E.	2	240		Weak	3	58	
Do.	NE. ¼ sec. 16, T. 32, R. 3 E.	2	270		do	4	58½	
Do.	SW. ¼ sec. 12, T. 32, R. 3 E.	2	310	1891	Weak now; 18 when drilled.	8	59½	
C. B. Larson	NW. ¼ sec. 15, T. 32, R. 3 E.	2	—300		1	1½ now	56	Overflows into pond or marshy place near house.
Nels Anderson	SW. ¼ sec. 21, T. 32, R. 3 E.	2			Just fair	3 or 4	59½	
Do.	NW. ¼ sec. 21, T. 32, R. 3 E.	2	340		Very weak	1	59	
Do.	NE. ¼ sec. 22, T. 32, R. 3 E.	2	400		None	No flow now		
Do.	Sec. 23, T. 32, R. 3 E.	2	400	1888		1 barrel		
Ferd Ashbre	Sec. 16, T. 32, R. 3 E.	2	40		Fair	5	59½	
Do.	Sec. 7, T. 32, R. 3 E.	2	300		Not strong		59	35 feet above river.
J. W. Gowery	Sec. 21, T. 32, R. 3 E.	2	327	1893	2		55½	
Do.	Sec. 21, T. 32, R. 3 E.	2	310		Weak	3	55	Just flows.
Herman Koch	NE. ¼ sec. 14, T. 32, R. 3 E.	2	270	1893	Could not gage	20	59½	
Fred Riefenrath	SE. ¼ sec. 12, T. 32, R. 3 E.	2	250		Was 12	8	57	Drilled about 12 years ago.
Do.	NE. ¼ sec. 23, T. 32, R. 3 E.	2	530	1886	Weak now	12	59	When first drilled this well was the cause of considerable trouble between its owner and parties owning land over which the water flowed.
Frank Reifenrath	SW. ¼ sec. 11, T. 32, R 3 E.	2	245	1887	Could not gage	11	57½	Owner could not give log. Casing at first 1½ inches; then 2 inches, and became strong again. Owner is 83 years old.
Chris Sartorius	SE. ¼ sec. 13, T. 32, R. 3 E.	2	255	1887		7		When first drilled volume 40 gallons per minute.
Swan Anderson	Sec. 24, T. 32, R. 3 E.	2	280		Weak	Enough to form quite a lake northwest of house.	69	Is piped to different lots about the barn. Runs in a large tile, 3 feet high, near the house. The pressure is little more than enough to lift the water to this level, as there is only a weak overflow. Temperature given was in the large tile.
J. C. Dawson	NE. ¼ sec. 24, T. 32, R. 3 E.	2				Horizontal pipe, 1 inch at top, full.	63½	
Do.	Sec. 24, T. 32, R. 3 E.	2	340	1890	Weak, pipe leaks	2	60	Much H_2S in water.
John Lammers	Sec. 35, T. 32, R. 3 E.	2	600	1885	Ceased flowing	All that 2-inch casing could hold.		

[a] 1½ inches, 1¼ now.

DIXON COUNTY.

The southwestern part of Dixon County resembles adjacent parts of Cedar County in topography, structure, and water conditions. In most other portions, except on the bottom land and along the bluffs on the Missouri, loess-covered hills predominate. The amount of sand and gravel beneath the loess appears to decrease to the northeast. The northwestern part of the county is underlain by Niobrara chalk rock. Glacial clay appears to be more widely distributed than in Cedar County.

Very little difficulty is experienced in obtaining a good supply of water, the Benton clays being the only beds that yield well water unfit for use. The principal water-power stream, the Aowa, is not strong, but inexpensive dams at Ponca and Martinsburg, constructed of brush, stone, and soil, afford water power for flouring and grist mills.

Springs.—Many springs occur in the county, one of the most notable of which is at Waterbury, where the flow has been used for locomotives. The water here rises from a considerable depth into a large circular basin near the station. One-half mile south a similar spring 45 feet across and 20 feet deep, flows between 300 and 400 gallons of water a minute, never freezing over during winter.

The Hurley Springs, about 5 miles west of Martinsburg, come out of sands above bowlder clay at an altitude of 1,425 feet. South of this place there is a general seepage from the slope at an altitude of 1,500 feet.

Shallow wells.—Much of the domestic water supply is from very shallow wells, which are affected somewhat by dry weather. In several localities the water table comes so near the surface that flowing wells might be had. One well 45 feet deep, at the stock yards in Allen, overflows. At Allen the water rises to within 12 feet of the surface, from a bed of gravel which lies at a depth of 70 feet. The following representative wells show the prevailing conditions in this county:

Representative shallow wells of Dixon County, Nebr.

Owner.	Location.	Depth.	Diameter.	Depth of water.	Quality.	Remarks.
		Feet.	*Inches.*	*Feet.*		
Town well of Wakefield	Sec. 32, T. 27 N., R. 5 E.	80	6	60	Very good, hard.	Black loam 10 feet; clay 30 feet; gravel.
J. W. Hypse	Sec. 24, T. 27, R. 4 E.	104	2	80	Hard	Black loam 4 feet; clay, sand, and gravel 100 feet.
Peter Norell	Sec. 25, T. 27, R. 4 E.	67	36	25	Bad, hard	Loam 2 or 3 feet; red clay, gravel, blue clay.
G. A. Herrick	Sec. 33, T. 29, R. 6 E.	27	3½	7		
R. C. Caulk	Sec. 9, T. 28, R. 5 E.	266	5	56	Hard	Yellow clay 111 feet; 31 feet to dry sand; dry gravel 18 feet; sand rock 1½ feet; dry sand 30 feet; 30 feet water; clay and sand 2 feet; water gravel 26 feet; light yellow clay 8 inches.
Benson Grain Co.	Sec. 26, T. 28, R. 6 E.	55	1½		do.	
Ioderson	NW. ¼ sec. 11, T. 29, R. 4 E.	155				Soil and loess 10; sand 6; yellow clay 34; blue clay (granules) 100; sand and water 5 feet.
Maggie Hurley	NE. ¼ sec. 10, T. 29, R. 5 E.	71	5	30	Hard	Soil, sand, and gravel mixed with clay, 15 feet; soil; blue clay to water.
D. Hurley	NE. ¼ sec. 2, T. 29, R. 5 E.	45	6	18	do.	Reached second water.
Lawrence Phillips	Sec. 7, T. 29, R. 5 E.	15	36	10	do.	
Dennis Hurley	Sec. 10, T. 29, R. 5 E.	26	3½	22	do.	Water in blue clay—affected very little in dry seasons.
Do.	do.	44	6	26		Can not be pumped dry.
J. E. Ekersoth	Sec. 22, T. 30, R. 6 E.	22	36	18	Hard	
Gilbert Bros.	Sec. 28, T. 30, R. 3 E.	60	36	14	do.	Soil, loess 40 feet; blue glacial clay 22 feet; sand and gravel.
A. Wiedenfeld	Sec. 6, T. 30, R. 4 E.	80	24	15		Loess 50 feet; cobblestone and gravel 5 feet; blue clay 25 feet.
Sam. Thomas	NW. ¼ sec. 24, T. 30, R. 4 E.	156		36		Loess 100 feet; sand 56 feet.
Nick Thomas	SW. ¼ sec. 12, T. 30, R. 4 E.	265		65		Loess 40, blue clay and sand 60, sand 150, and shaly clay 15 feet.
John Rahn	NW. ¼ sec. 34, T. 30, R. 5 E.	301		Many.		Loess 60, blue clay (Benton) 210, sandstone with water (Dakota) 29 feet.
O. J. Anderson	NE. ¼ sec. 33, T. 32, R. 4 E.	167		10	Good	Loess 130, dry sand 11, sandy clay 8, and fine sand with water 18 feet.

Artesian wells.—There are a few artesian wells on the bottom lands in the northern part of the county. If wells were sunk to the lower beds of the Dakota formation and carefully cased, flows could be had several miles farther southeast. There are also a number of deep tubular wells located on high land south of the Missouri bottom. The following wells are now flowing:

Artesian wells of Dixon County, Nebr.

Name.	Location.	Depth.	Diameter.	Length of casing.	When drilled.	Pressure.	Yield per minute.	Temperature.	Remarks.
		Feet.	*Inches.*	*Feet.*		*Pounds.*	*Gallons.*	*F.°*	
Chris Sartorious	Sec. 19, T. 32 N., R. 4 E.	300	2	70		Weak	2	61	Pipe leaks.
Fred Reifenrath	Sec. 19, T. 32, R. 4 E.	300	1½	65		do	2	61	Pipe rusted.
J. P. Warnick	Sec. 29, T. 32, R. 4 E.	280	2	60	1893	2 now	1	61	Pressure 8 pounds when drilled.
Do	NE. ¼ sec. 29, T. 32, R. 4 E.	280	2	70	1898	Weak (leaks)		60½	Flows pipe half full.
C. Weeks	Sec. 28, T. 32, R. 4 E.	290	2	At first 50; now 1-inch pipe to bottom.		5½		60½	Flowed at 240 feet. Pressure 9 pounds when drilled.
Thomas Warnick	NW. ¼ sec. 28, T. 32, R. 4 E.	277	2	60	1899	6 now; was 8		60¾	Sand, 70 feet; limestone and clay, 80 feet; sandstone and water, 27 feet.
Do	Sec. 28, T. 32, R. 4 E.	177	2	60	1901	Weak		59	Shallowest well in this region.
Butler Bros.	Sec. 34, T. 32, R. 4 E.	300	2			None	1	58	Pipe rusted off.
Dexter Rice	Sec. 28, T. 32, R. 5 E.	265	2	40	1888	Nearly 10		61	Pressure 10 pounds when drilled. First flow at 160 feet.
T. J. Ryan	Sec. 32, T. 32, R. 5 E.	265	2	At top 3 inches in diameter.	1896	2 now	3	55	Pressure 8 pounds when drilled.
Do	Sec. 32, T. 32, R. 5 E.	400	2		1886	12½ originally	3	54	Flowed 50 gallons when drilled.
Geo. Mathison	Sec. 20, T. 31, R. 6 E.	484	3		1888	None			Flowed 3 weeks. Rises within 3 feet of top.

DAKOTA COUNTY.

Dakota County resembles Dixon in configuration but includes a much wider area of bottom lands along the Missouri. Its uplands are deeply trenched by the small valleys of many watercourses, with the intervening ridges or plateau remnants thickly capped by loess. Cretaceous rocks from Dakota to Greenhorn appear in the slopes and often present extensive outcrops. The Missouri bottom land is thickly floored by alluvial deposits.

The principal stream is Missouri River, which defines the eastern boundary. There are several creeks of moderate size, the most notable of which is Elk Creek, a stream which flows with a remarkably crooked course north from Emerson to Goodwin, then east and southeast to Jackson, and finally southeast and east to the river northeast of Homer. There is much surface water, but the principal water supplies are from the numerous springs and shallow wells.

Springs.—Many springs issue from the Dakota sandstone, which outcrops from above Jackson to the southeastern part of the county. These afford an abundance of good cool water for drinking, domestic purposes, and stock. A spring in sec. 24, T. 28 N., R. 8 E., 2 miles northwest of Homer, has been used for forty-eight years for domestic supply and as a public watering place. It flows 6 gallons a minute, with a temperature of 51°.

The Miller Spring, a short distance northwest of Homer, is piped from a tile sunk in the sand; part of the flow fills a 1-inch pipe.

At a ranch a half mile north of Homer the sand rock has been dug into and a reservoir walled up, from which runs enough water to fill a 2-inch pipe. A half mile north of this place there is one of the strongest springs in the vicinity, and about 6 miles southwest of Jackson there are two very strong springs.

Wells.—Underground-water conditions are much the same as in Dixon County, except that the Dakota sandstone rises nearer to the surface and is easily reached by tubular wells. There are no artesian wells in the county; the artesian water reached in such wells farther west issues here as springs.

The following is the record of a tubular well on high ground 6 miles southwest of Jackson: Loess, 90 feet; sand and hard spongy clay, 6 feet; dark clay with a bed of limestone near the middle, 156 feet; sand rock with good water, 6 feet.

Wells on or near the bluffs between Jackson and Homer are usually 80 to 100 feet deep, but several in Jackson are deeper. The Ashford well at Homer is 184 feet deep. The supply is usually good, but in the Ashford well the water is poor on account of improper casing through clay beds which carry soluble salts. On the bottom lands the depth to the first water varies from 20 to 25 feet, but at 35 feet the water is usually poor. Formerly most wells were drilled to the greater depth, but now they are driven to the first water. According to reports by well drillers the alluvium southeast of Jackson is from 80 to 100 feet deep. A steady supply of good drinking water is obtained at Homer in a well 40 feet deep. In the southwestern part of the county wells are very shallow, but yield inexhaustible supplies.

AGRICULTURAL RESOURCES.

SOILS.

The soils of the region are of several types, having been formed by various agencies acting on rocks of different kinds; most of them are closely related to the underlying formations. Much of the eastern and central parts of the area lies in the fertile loess region, where the soil is deep and easily worked, receives and holds moisture well, and yields heavy crops on both hilly and level lands. The alluvial bottom-land or flood-plain soil is also fertile and easily tilled, but in the lowest areas fields are often damaged by high waters and by shifting of the river channel. The heavy Pierre clay, or gumbo soil, is especially extensive in Boyd County; it contains some alkali and often affords bad water, but usually produces good grass and heavy yields of corn, oats, and wheat, especially where the clay is mixed with sand. The sandy upland soils in Cedar, Knox, Holt, and western Boyd counties stand droughts well and are gradually being utilized.

CROPS.

The principal crops are hay, corn, wheat, and oats, but alfalfa and sugar beets are also successfully grown. Mixed farming is practiced generally, except at points where the land is too sandy, or the topography is not favorable. Every county has a large acreage of hay land; in Cedar County this crop is grown principally along broad creek basins. While corn grows well throughout most of the region, it does best at certain points on the Missouri bottom. The heaviest yield of oats per acre in 1903 was in Boyd County, southeast of Spencer, and near Gross. Grain elevators are found at every railroad station. The reported acreage of the principal grain crops in 1902, not including Holt County, was as follows: Corn, 279,055; wheat, 105,981; oats, 115,958; rye, 12,680; barley, 4,877.

STOCK RAISING AND DAIRYING.

One of the most important industries in the region is cattle raising, and in many localities wide areas are used for grazing, especially where the land is too rough or too sandy for farming. The principal pasture lands are in the northern part of the Santee Indian Reservation in Knox County, in southwestern Knox County, in the sandy and rough portions of Holt and western Boyd counties, and on the bluff and ravine lands along Missouri River. Hogs, sheep, and horses are also raised in large numbers.

Dairying has attained an important place in the economy of the region. Cream is shipped from nearly all the railroad stations, Holt County leading in its production in the State of Nebraska.

TIMBER.

The timber growth is of considerable importance in most of the counties. It occurs mostly along the river and creek bottoms and up many ravines. The principal trees of economic importance are cottonwood, bur oak, elm, and scattering walnut; some of these are as much as 4, 5, or even 6 feet in diameter. The timber is used for posts, firewood, lumber, frames, and bridges. Sawmills operate at a number of points, as north of St. Helena, northwest of St. James, on Brooky bottom, and west of Aten. The sawmills obtain their timber principally from caving banks along the rivers, where the timber would be rapidly destroyed if not removed. The bur-oak growth is thickest in northern Dixon and Cedar counties, where it is cut into posts for which there is much demand. Timber cutting begins about September and lasts during the autumn and winter.

INDEX.

Page.

- Agricultural resources, character of........ 55–56
- Allen, well at........ 50
- Alluvium, character and distribution of.... 21
- Aowa Creek, sections near........ 7
- Arikaree formation, character and distribution of........ 8, 18–19
  - quarrying of........ 22
  - water in........ 26
- Artesian conditions, description of........ 28
- Artesian water, analysis of........ 29
  - composition of........ 28–29
  - pressure of........ 29–30
    - diminution of........ 31
  - temperature of........ 30
- Artesian wells. *See* Wells, artesian.
- Aten, building stone near........ 23
- Badger Bridge, building stone near........ 22
  - section near........ 19
  - wells at........ 38
- Bazile Creek, sections on........ 15, 17
  - water powers on........ 40
    - view of........ 40
- Bazile Point, section at........ 15
- Belemnitella, occurrence of........ 16
- Benton group, character and distribution of........ 10–13
- Blowing wells. *See* Wells, blowing........ 31
- Blow-outs, occurrence of........ 22
- Bluff deposit, character and distribution of. 20–21
- Bow Creek, wells on........ 46
- Boyd County, altitudes in........ 39
  - artesian wells in........ 38–39
  - shallow wells in........ 36–37
  - springs in........ 35–36
  - streams in........ 35
- Brick clay, occurrence and use of........ 22
- Building stone, occurrence and use of........ 22–23
- Burchard, E. F., on Graneros shale........ 11
- Butte, building stone at........ 22
  - wells at........ 36
- Carboniferous rocks, character and distribution of........ 6
  - water in........ 28
- Carlile shale, character and distribution of.. 12–13
  - concretions in, view of........ 12
  - contact of Niobrara and, view of........ 12
  - section of........ 13
- Cedar County, artesian wells in........ 46–49
  - shallow wells in........ 45–46
  - springs in........ 45
  - water in, pressure of........ 29
- Cement plant, description of........ 23
  - view of........ 24
- Cement rock, character and distribution of........ 23–24

Page.

- Cement rock, outcrop of, view of........ 24
- Center, building stone near........ 23
  - section near........ 17
  - springs near........ 40–41
- Chamberlain, ——, data from........ 46
- Cleveland, C. C., on his blowing well........ 31–32
- Coal, character and distribution of........ 24
- Coleridge, springs at........ 45
- Concretions, occurrence of........ 12
- Cook Creek, loess near........ 21
- Creighton, blowing well at........ 31
- Cretaceous rocks, character and distribution of........ 6, 8–17
  - water from........ 27
- Crops, character of........ 55
- Dairying, importance of........ 56
- Dakota County, springs in........ 54
  - wells in........ 54–55
- Dakota sandstone, character and distribution of........ 8–10
  - dip of........ 8
  - quarrying of........ 23
  - sections of........ 9, 10
  - view of........ 10
  - water from........ 27, 28
- Darton, N. H., on Benton group........ 10
  - work in charge of........ 5
- Dixon County, artesian wells in........ 52–53
  - shallow wells in........ 50–51
  - springs in........ 50
  - water in, pressure of........ 29
- Dune sands, character and distribution of... 22
- Eagle Creek, landslides on........ 16–17
- Elk Creek, drainage of........ 54
- Fort Randall, section near........ 17
- Frankforter Creek, character of........ 40
  - springs on........ 41
- Geology, description of........ 6–22
- Geology, economic, description of........ 22–55
- Glacial drift, character and distribution of.. 20
- Graneros shale, character and distribution of........ 11
  - contact of Greenhorn limestone and, view of........ 10
- Gravel, occurrence and use of........ 22
- Greenhorn limestone, character and distribution of........ 11
  - contact of Graneros shale and, view of........ 10
  - fossils of, view of........ 14
  - quarrying of........ 23
  - section of........ 11
- Gross, well water at........ 36
- Gumbo. *See* Pierre shale.
- Holt County, artesian water of........ 34–35

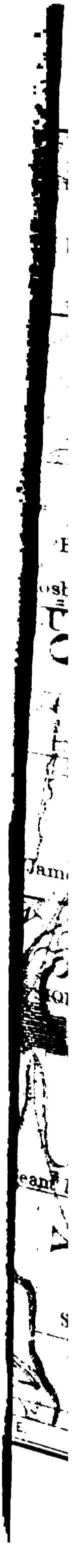
Page.
Holt County, shallow wells of 34
  springs of 33-34
  topography of 32-33
  water powers of 33
Homer, building stone at and near 23
  coal near 24
  sections near 9, 10
  springs near 54
  wells at 54
Ice, crumpling by 15
Inoceramus, occurrence of 7, 11, 12, 15, 16
  labiatus, occurrence of 7
    view of 14
Ionia, section near 10
Ionia Volcano, nature of 12
  section at 12
Irrigation, use of 33-34
Jackson, building stone at 23
  coal near 24
    analysis of 24
  section at 10
  well near, record of 54
James, rocks near, view of 12
Keyapaha River, drainage of 35
  geology near 19
Knollkemper, William, dam of 33
  dam of, view of 18
Knox County, artesian wells in 41-44
  shallow wells in 41
  springs in 40-41
  streams in 40
  topography of 39-40
  water powers in 40
Landslides, occurrence of 16-17
Lignite, occurrence of 9
Loess, character and distribution of 20-21
Logan Creek, sand dunes on 22
Loveland, G. A., precipitation data from 25
Lynch, artesian wells at 34, 35-36, 38
  artesian wells at, pressure on 29-30
    record of 38
    view of 38
    water from, analysis of 39
Mackeyville, section near 17
Map of Nebraska 6
  of northeastern Nebraska, showing underground-water conditions. Pocket.
Map, geologic, of northeastern Nebraska. Pocket.
Martinsburg, springs near 50
Mineola, blowing wells near 31
Mineral resources, description of 22-24
Missouri River, bluffs of 14
  Dakota sandstone on, view of 10
  drainage of 35, 40
  water of 25-26
Monowi, building stone near 22
  wells at 36
Niobrara, cement rock near 23
  cement rock near, view of 24
  springs near 40
  wells at 41
    pressure of 29
    record of 43
Niobrara formation, analysis of 15
  character and distribution of 13-15
  contact of Carlile clay and, view of 12
  fossils of, view of 14

Page.
Niobrara formation, quarrying of 23
  sections of 14, 15, 17
  view of 24
Niobrara River, discharge of 26
  drainage of 32-33, 35, 40
  geology on 16
Ostrea congesta, occurrence of 7, 12, 14, 15
  view of 14
Paddock, springs near 33
Peat, character and distribution of 24
Perrin Creek, peat near 24
Phoenix, springs near 33
Pierre shale, character and distribution of 15-17
  limestone in, quarrying of 23
  section of 15
Pliocene deposits, character and distribution of 19-20
Ponca, rocks near, view of 10
Ponca Creek, drainage of 35
  flow of 26
  springs on 36
  wells on 38
Ponca Landing, coal near 24
  section near 11
Precipitation, records of 25
Pressure in artesian wells, diminution of 31
  variations in 29-30
Prionocyclus, occurrence of 7, 12
Quaternary deposits, character and distribution of 20-22
  water from 27
Ray, building stone at and near 22
  springs near 33
Riggs, R. O., analysis by 28-29
Rosebud Agency, water at, pressure of 30
Rosedale, well at 39
St. Helena, well at, record of 46
St. James, section near 14
Sand, occurrence and use of 22
Santee Agency, well at 43
  well at, record of 43
    view of 40
Sections across northeastern Nebraska, plate showing Pocket.
Selenite, occurrence of 12
Serpula, occurrence of 7, 12
Soapstone. *See* Pierre shale.
Soils, character of 55
Spencer, building stone near 22
  section near 17
  springs near 35
  wells at 38
Springs, character and distribution of 26-27
Stock raising, industry of 55-56
Stone, building, occurrence and use of 22-23
Stony Butte, building stone near 22
  description of 18
Stout, R. F., fossils found by 16
Stratigraphy, description of 6-8
Streams, character and distribution of 25-26
Structure, description of 8
Surface waters. *See* Waters, surface.
Temperature of artesian water, increase of 30
Tertiary rocks, character and distribution of 7-8, 18-20
  section of 19
  water from 27

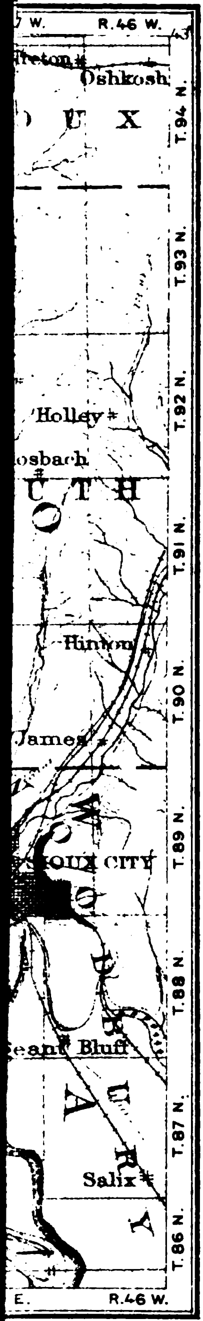
Page.
Timber, character and distribution of 56
Todd, J. T., aid of 5
  on geology of region 9, 13
Topography, description of 6
Turner, building stone at 22
  springs near 33
Twin Buttes, building stone near 22
  description of 18
  section near 20
  view of 18
Underground water. *See* Water, underground.
Verdel, building stone near 22
Verdigre, building stone near 22-23
  springs near 40
  water power at 40
Vermillion Ferry, rocks near, view of 12
Volcanic ash, occurrence of 24
Water powers, character and distribution of 26
Water resources, description of 25-55
Water, artesian. *See* Artesian water.

Page.
Waterbury, springs at 50
Water, surface, character and distribution of 25-27
Water, underground, character and occurrence of 27-32
  character and occurrence of, map showing Pocket
  See also Artesian water.
Wells, artesian, character and distribution of 28-31
  construction and care of 30-31
  view of 38, 40
  See also Artesian water.
Wells, flowing, character and distribution of 31-32
Wells, shallow, character and distribution of 27-28
  pollution of 32
Whiting Bridge, section near 17
Wiegand, springs at 41
Yankton, S. Dak., cement plant near 23
  cement plant near, view of 24
  cement rock near 23

O

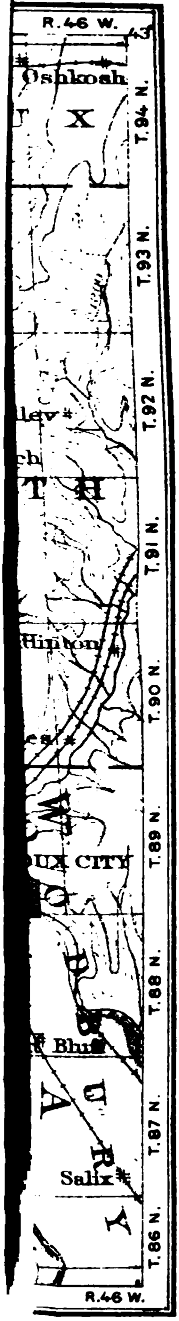


NO. 215 PL. II



R.46 W.
Oshkosh
U X
T.94 N.
T.93 N.
Holley
T.92 N.
osbach
U T H
O
T.91 N.
Hinton
T.90 N.
James
T.89 N.
SIOUX CITY
W
O
T.88 N.
Bluff
B
T.87 N.
A
R
U
Salix
Y
T.86 N.
E.
R.46 W.

15 PL. IX


R.46 W.
43
Oshkoah
X
T.94 N.
T.93 N.
ley
ch
T H
T.92 N.
T.91 N.
Hinton
T.90 N.
es
T.89 N.
UX CITY
W
O
B
T.88 N.
Bluff
A
U
R
T.87 N.
Salix
Y
T.86 N.
R.46 W.

Water-Supply and Irrigation Paper No. 216

Series
A, Economic Geology, 97
B, Descriptive Geology, 119
M, General Hydrographic Investigations, 26
O, Underground Waters, 72

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGY AND WATER RESOURCES OF THE REPUBLICAN RIVER VALLEY AND ADJACENT AREAS, NEBRASKA

BY

G. E. CONDRA

WASHINGTON
GOVERNMENT PRINTING OFFICE
1907

CONTENTS.

Page.
Introduction 7
Geography 8
  Topography 8
  Drainage 8
  Climate 9
    Temperature 9
    Rainfall 9
    Winds 10
Descriptive geology 10
  General relations 10
  Structure 11
  Description of the rocks 11
    Carboniferous system 11
    Cretaceous system 12
      Dakota formation 12
          Character and thickness 12
          Distribution 13
      Benton group 13
        Members represented 13
        Graneros shale 14
          Character and thickness 14
          Exposures 14
        Greenhorn limestone 14
          Character and thickness 14
          Fossils 16
        Carlile shale 16
          Character and thickness 16
          Exposures 16
      Niobrara formation 17
          Character and thickness 17
          Fossils 18
          Distribution 18
      Pierre shale 18
          Character and thickness 18
          Distribution 19
    Tertiary system 19
          Character and thickness 19
          Distribution 20
    Quaternary system 20
      Drift 20
      Loess 23
      Terrace deposits 23
      Alluvium 24
      Dune sands 25

Page.
Economic geology 25
  Mineral resources 25
    Coal 25
    Petroleum and natural gas 26
    Building stone 26
    Cement 28
    Clay 28
    Sand and gravel 28
    Volcanic ash 30
    Ocher 30
Water resources 31
  Surface waters 31
    General character 31
    Republican River 31
    Frenchman River 34
    Redwillow and Medicine creeks 35
    Beaver and Sappa creeks 35
    Prairiedog Creek 35
    Little Blue River 36
    Springs 36
    Lakes 37
  Underground waters 37
    Source of ground waters 37
    Quality 38
    Depletion of supply 38
    Shallow wells 39
    Weak and dry wells 39
    Blowing wells 41
    Pollution of shallow wells 42
    Windmill pumping 43
    Irrigation from wells 43
    Artesian wells 43
  Water supply, by counties 45
    Dundy County 45
    Hitchcock County 46
    Redwillow County 48
    Furnas County 50
    Harlan County 51
    Franklin County 52
    Webster County 54
    Nuckolls County 55
    Thayer County 55
    Jefferson County 57
  Water power 58
    General statement 58
    Power sites in the Republican Valley 59
    Power sites in the Little Blue River basin 60
  Irrigation 60
Agricultural resources 61
  General statement 61
  Soils 61
  Crops 62
    Native grasses and their utilization 62

Page.

Agricultural resources—Continued.

Crops—Continued.

Cultivated forage crops 63

Grain crops 63

Fruit raising 64

Sugar beets 64

Stock raising and dairying 65

Timber 66

Index 67

ILLUSTRATIONS.

Page.

PLATE I. Map of Nebraska, showing area treated in this report 7

II. Geologic map of the Republican and Little Blue valleys 10

III. Sections across southern Nebraska along vertical lines shown in Pl. II 12

IV. *A*, Dakota sandstone east of Endicott; *B*, Niobrara limestone near Norton, Kans., showing small fault 14

V. *A*, Lookout Mountain southeast of Franklin, showing bluffs capped by Tertiary sandy lime rock; *B*, Tertiary "mortar beds" on Pierre shale east of Haigler; *C*, Tertiary gravel near head of Trail Canyon, Dundy County 20

VI. *A*, Quartzite bowlder northeast of Fairbury; *B*, Glacial bowlders southeast of Endicott 22

VII. *A*, Terraces near mouth of Trail Creek, Dundy County; *B*, Wind erosion in high terrace west of Benkelman 24

VIII. *A*, Niobrara limestone quarry northeast of Cambridge; *B*, Typical sand hills northeast of Haigler 26

IX. *A*, Republican River south of Bostwick; *B*, Sandhill Lake, Dundy County 32

X. *A*, Falls of Frenchman River at Wauneta; *B*, Spring in Dundy County 34

XI. *A*, McAlee irrigation plant at Benkelman; *B*, Windmill in sand hills of western Nebraska 44

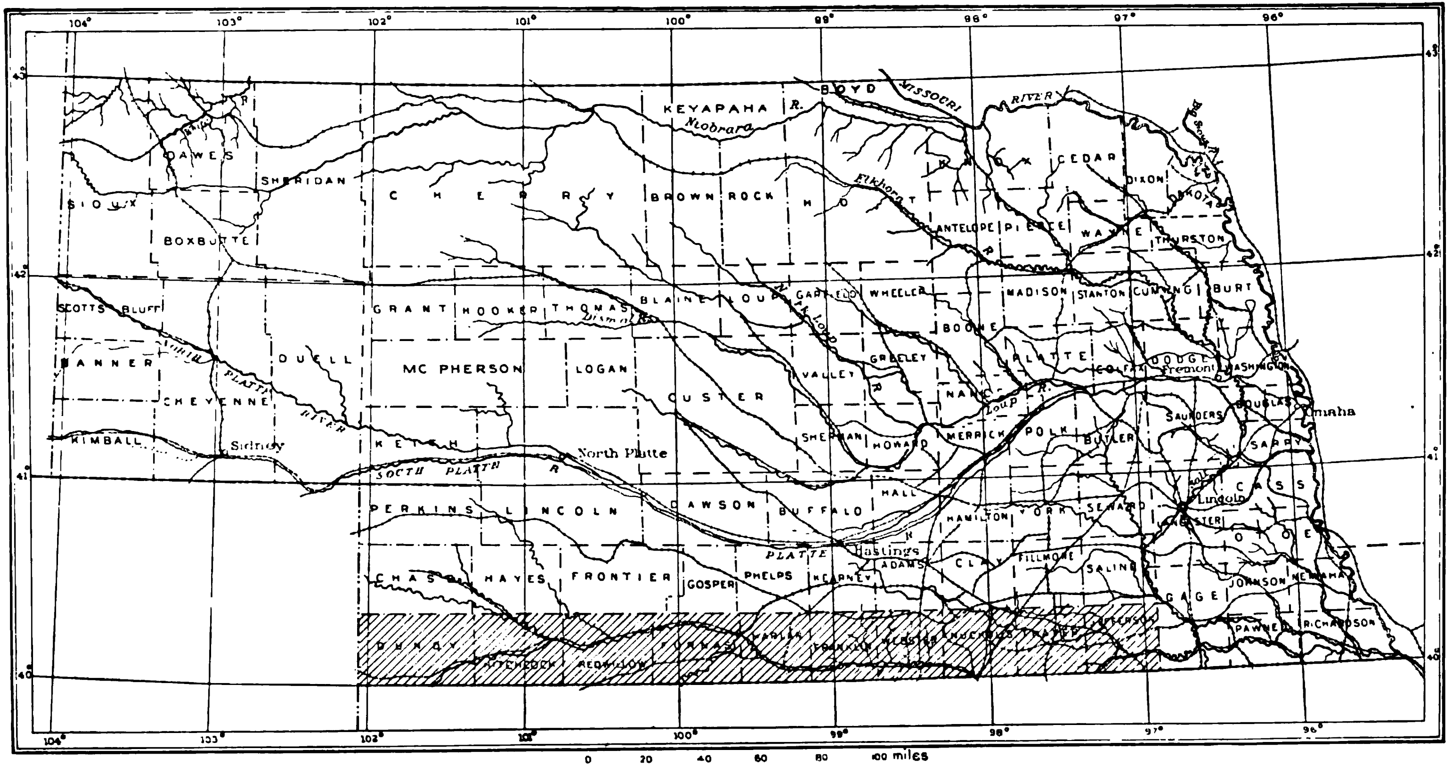
XII. *A*, Artesian well and reservoir at Alexandria; *B*, Dam in Republican River at Superior 46

XIII. *A*, Irrigated alfalfa field northwest of Haigler; *B*, Bur-oak grove near Endicott 60

FIG. 1. Diagram of rainfall in southern Nebraska 9

2. Section to illustrate ground-water relations 40

3. Section showing blowing-well conditions 41



MAP OF NEBRASKA, SHOWING AREA TREATED IN THIS REPORT.

GEOLOGY AND WATER RESOURCES OF REPUBLICAN RIVER VALLEY AND ADJACENT AREAS NEBRASKA.

By G. E. CONDRA.

INTRODUCTION.

The region described in this report is the portion of southern Nebraska lying between latitude 40° and 40° 20′ and longitude 97° and 102°. It is 22¾ miles wide and 272½ miles long, and comprises an area of about 6,199 square miles. As shown in Pl. I, it includes the greater part of 10 counties, which are, from east to west, Jefferson, Thayer, Nuckolls, Webster, Franklin, Harlan, Furnas, Redwillow, Hitchcock, and Dundy. They lie along the Kansas border, extending from the vicinity of Fairbury westward to the Colorado State line.

This report is the result of general observations made during several consecutive seasons and of special field studies made by the writer under the direction of N. H. Darton during the summer of 1904. Considerable information concerning this region, collected by the Nebraska geological survey, has been furnished by Prof. E. H. Barbour. Numerous well records have been given by well drillers, business men, county superintendents, and teachers. The writer is also indebted to Messrs. U. G. Cornell, George A. Loveland, J. C. Stevens, E. N. Averill, N. J. Allen, and F. A. Carmony for valuable information.

Topographic maps are available for a portion of this area, the following sheets having been published by the United States Geological Survey: Hebron, Superior, Red Cloud, Holdrege, and Arapahoe. The topography for the remainder of the area has been compiled from barometer readings and railroad data.

GEOGRAPHY.

TOPOGRAPHY.

The area covered by this report is part of the Great Plains. It extends over portions of three fairly distinct physiographic regions—the high plains or table-lands, the loess plains or prairies, and the sand hills, each region possessing characteristic topography and drainage.

The general slope of the higher plains or upland surface is eastward from an altitude of about 3,600 feet in the western part of Dundy County to about 1,400 feet in the eastern part of Jefferson County, at an average rate of about 8 feet to the mile. The lowest altitudes are along the valleys in Jefferson County, being less than 1,250 feet south of Steele City. In most of the area, except in the sand hills, the topography has been developed by the action of running water, but in Jefferson County the great ice sheet of the Glacial epoch was an important factor in shaping the surface and developing its drainage.

The loess plains are relatively smooth and in greater part have practically no surface drainage, but where they are cut into by water courses there are deep canyons bordered by precipitous walls. Some of these canyons are long and deep, notably Trail Canyon, 4 miles east of Haigler, where there is a fall of 300 feet in a distance of less than 2 miles.

The sand hills, which are an outlying area of the great sand-hill region of Nebraska, extend from the north-central part of the State to its southwestern corner. The largest district treated in this report is in Dundy County north of Republican River and west of Rock Creek. The characteristic topographic forms are rounded sand dunes, sand ridges, blow-outs, dry valleys, and basins, with no run-off water except at the edge of the hills. Water often collects in some of the basins during the rainy season, forming small lakes.

DRAINAGE.

The principal streams in the area are Republican and Little Blue rivers. The course of the former corresponds in direction with the general eastward slope of the country. Its bed lies 200 to 400 feet below the bordering uplands, and its valley slopes, though generally rough, vary somewhat in character from place to place, according to the varying nature of the geologic formations which the stream traverses. The valley itself and the valleys of the tributaries are generally wide and bordered by a definite system of terraces.

The valley of Little Blue River is nearly as wide as that of the Republican, but is somewhat shallower, and its direction is diagonal to the general eastward slope of the surface. Near Powell it turns southward at right angles to its first course, a change possibly due to the former presence of the glacier in this vicinity.

CLIMATE.

TEMPERATURE.

The mean annual temperature in Jefferson County and in most of the region as far west as Hitchcock County is about 51°, but farther west it decreases to an average of 50°. The warmest month is July and the coldest January. East of Furnas County the number of days without frost during the year varies from 155 to 165. The latest frost of spring occurs between April 25 and May 1, and the first frost of autumn about October 1. In Furnas County and the remaining area to the west the average number of days without frost varies from 145 to 150. The latest frosts of spring occur between May 1 and May 5, and the earliest of autumn between September 25 and October 1.

RAINFALL.

The average annual rainfall at eight stations is shown in fig. 1. The stations are located at regular intervals from east to west across the area, but the time during which records have been kept at the different stations varies in length from eleven to twenty-eight years. The heaviest rainfall is in May, June, and July, with light precipitation during the winter months. The snowfall is slight, especially in Dundy County, but farther east it increases somewhat in amount. In the summer occasional hailstorms occur throughout the region, but are most frequent in the western portion, where they often do considerable damage to crops. Cloudiness is greatest in the east, giving way in the west to increasing sunshine and a lower degree of humidity.

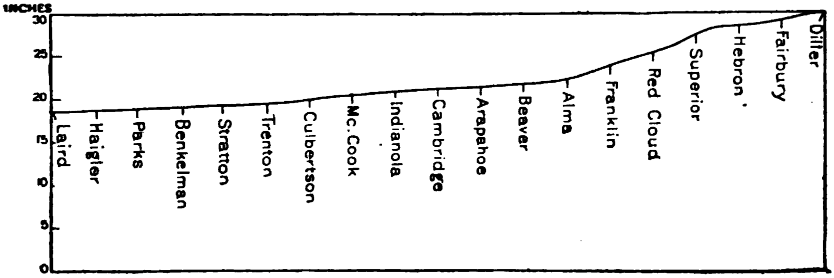


FIG. 1.—Diagram showing the decrease of mean annual rainfall from east to west in southern Nebraska.

Normal precipitation, in inches, at eight stations in southern Nebraska.

Place.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Fairbury	0.75	0.74	1.63	2.75	4.74	4.61	4.80	3.13	2.45	2.38	0.79	0.63	2
Hebron	.77	.68	1.46	2.62	4.69	4.74	4.38	3.48	2.37	2.14	.96	.66	2
Superior	.57	.78	1.06	2.98	4.00	4.31	4.92	2.82	2.36	2.24	.72	.57	2
Red Cloud	.33	.59	.77	2.27	3.32	4.75	4.30	2.73	2.77	1.81	.59	.51	2
Franklin	.42	.63	.89	2.48	3.86	3.58	3.34	2.87	2.82	1.90	.42	.45	2
Beaver	.25	.62	.77	2.48	3.18	3.90	3.60	2.28	2.03	1.14	.54	.41	2
Culbertson	.37	.63	1.05	2.36	2.76	3.56	2.94	2.74	1.52	1.05	.36	.36	1
Haigler	.19	.39	.81	2.01	2.99	2.78	2.91	2.73	1.21	.77	.43	.26	17

WINDS.

No reliable data are available as to wind velocity, but the wind generally stronger in the western counties than in those farther east.

DESCRIPTIVE GEOLOGY.

GENERAL RELATIONS.

Southern Nebraska is underlain by various formations of Cr taceous age lying unconformably on Carboniferous formations a extensively overlain by Tertiary and Quaternary deposits; ori nally the latter covered the entire surface, but they have now be removed in the deeper valleys.

The relations underground of the Cretaceous formations ha been revealed by deep well borings. They are of sedimenta origin, consisting of shale, sandstone, limestone, and chalk, and l nearly level in a succession of widespread sheets. In the wester part of the region they reach a thickness of 4,000 feet or more, bu owing to erosion they thin out to the east. The Tertiary and Quaternary deposits consist of sands, loams, clays, bowlders, calcareous grit, and sandstone.

The formations outcropping in this area are as follows:

- Quaternary
  - Dune sands.
  - Alluvium.
  - Loess.
  - Drift.
- Tertiary
  - Ogalalla.
  - Arikaree.
- Cretaceous
  - Pierre.
  - Niobrara.
  - Benton:
    - Carlile.
    - Greenhorn.
    - Graneros.
  - Dakota.

kota sandst

The distribution and general structural relations of these formations are shown in Pls. II and III. The oldest is the Dakota sandstone, which underlies all of the region discussed, and is in turn underlain unconformably by Permian limestones and shales which outcrop extensively farther east in Nebraska and southeast in Kansas. The overlying formations occur in regular order, but do not extend over the entire area.

STRUCTURE.

In southern Nebraska the rocks lie nearly horizontal, but, as shown in the section on Pl. II, with a general westerly inclination, interrupted near Cambridge by a low uplift or arch discovered by Mr. Darton several years ago. This arch develops in northwestern Kansas and extends northwestward across Nebraska. Its configuration is defined by the relations of the Niobrara formation, which is uplifted 200 feet or more near the crest of the arch in the vicinity of Cambridge. From the crest the Pierre shale and 100 feet or more of the Niobrara have been eroded in the central and western portions of Furnas County. On the west side of the anticline the strata dip westward at an unknown but moderately rapid rate, so that in the extreme southwestern corner of Nebraska the top of the Niobrara formation is at a depth of about 2,000 feet, judging by the structure in adjoining portions of Colorado. East of the anticline there is a shallow syncline which holds Pierre shale from Arapahoe east to Naponee; thence eastward the strata rise gradually, and formations from Niobrara to Dakota outcrop in regular succession in the counties from Franklin to Jefferson. In general the rate of inclination is regular and averages 3 feet in a mile. Locally, however, the rate is very much increased, especially in portions of Jefferson County. A local flexure is presented by the Greenhorn limestone in the southern portion of Jefferson County, and steep local dips of 10° or more occur to the southwest, in the exposure of Dakota sandstone south of Thompson, Nebr. The Dakota formation presents also a low anticline in the vicinity of Thompson and Gladstone, with the upper part of the arch removed by erosion. Faults, showing a few inches of displacement, occur in the Niobrara chalk in a number of places, one of the best defined examples being at Norton in beds dipping gently westward. This fault is shown in Pl. IV, *B*.

DESCRIPTION OF THE ROCKS.

CARBONIFEROUS SYSTEM.

A short distance east of Jefferson County Permian limestones and shales—the upper series of the Carboniferous system—rise from beneath the Dakota formation and appear in many outcrops. They undoubtedly underlie the area treated in the report but at increasing depth to the west, and it is possible that they immediately underlie the alluvium in the vicinity of Diller and along the Little Blue River Valley below Steele, where they are known to come close to the surface. The following is a typical section of the Permian beds which pass under the Dakota sandstone in southeastern Nebraska:

Section at the J. P. McAllister quarry, 1 mile southeast of Odell.

	Feet.
Limestone, fossiliferous, weathered	⅔
Clay, light buff	4
Limestone, grayish, but rusty at places, massive, even grained, with few fossils; used for building stone	1½
Clay, buff colored	4
Clay, ocherous, reddish to brownish	12
Limestone, clayey, decayed	5
Limestone, flinty	1½
Clay and decayed limestone, exposed in ravine	?

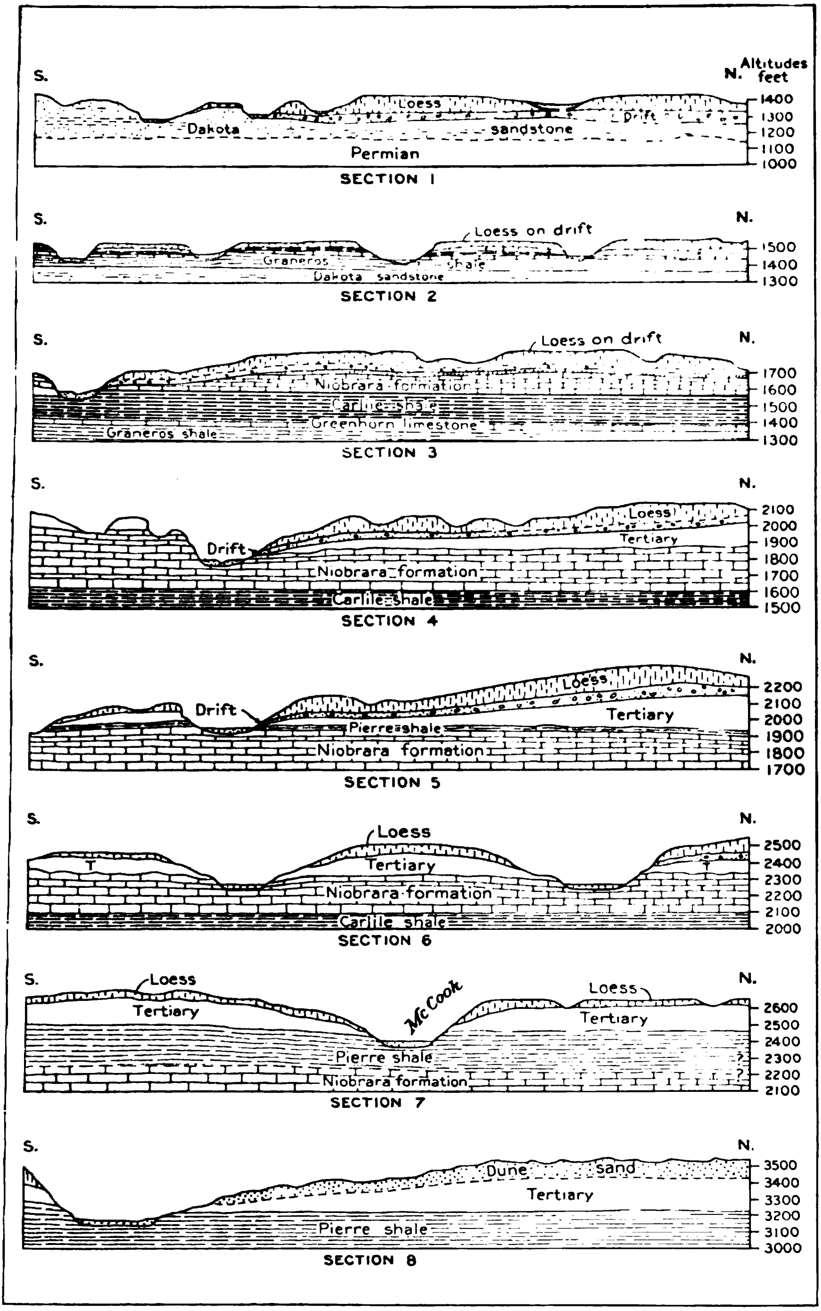
In eastern Nebraska the upper surface of the Permian rocks was a land surface in early Mesozoic time, while in the Rocky Mountain region west there was deposition of early Cretaceous, Jurassic, and Triassic sediments. Possibly some of these reach the western portion of the area treated in this report, but of this there is no evidence.

CRETACEOUS SYSTEM.

DAKOTA FORMATION.

Character and thickness.—The Dakota formation in this region consists of sandstone and clay, with the former generally predominating. While the formation as a whole shows considerable variation in stratigraphy, in most localities it is possible to recognize three members—a basal sandstone member, a medial clay member, and an upper sandstone and shale member. The lower sandstone is a medium to coarse grained variety, occurring in beds which are usually massive and cross-bedded, although in places thin bedded. Its color is gray or pale buff, but on exposed surfaces it is generally rusty brown, and portions of it are often stained to a deep brown. The clays are variegated, with red and green predominating. In some places they are more or less sandy, and thin beds of relatively pure sandstone are not infrequent. The clay is overlain by a massive, cross-bedded, dark-brown sandstone, which constitutes the upper member of the formation. This sandstone sometimes contains concretionary masses which are lighter colored and more compact than the remainder of the rock. Associated with the sandstones of the upper part of the formation are thin beds of impure lignite coal.

The Dakota formation south of Kesterson is about 275 to 300 feet thick, but the beds may thicken somewhat to the west. It is overlain



SECTIONS ACROSS SOUTHERN NEBRASKA ALONG VERTICAL LINES SHOWN ON PL. II.

conformably by the Graneros shale and unconformably by Quaternary deposits. It rests upon the eroded surface of the underlying Permian, as is indicated by the differences in altitude of the base of the formation. Many species of well-preserved fossil leaves of Upper Cretaceous age have been found in the Dakota sandstone, especially in Jefferson County. A section near Steele is as follows:

Section of Dakota formation in slopes west of Steele.

	Feet.
Sandstone, brownish, usually massive	40–60
Clay, light buff to ocher yellow	80–110
Sandstone, rusty, massive	40–55

Distribution.—The Dakota formation is extensively exposed in Jefferson County, in the eastern part of the region, where it outcrops in an area of varying width, extending across the southern townships of the county westward to a point about 6 miles west of Reynolds, where, with low westerly dip, it passes beneath the overlying formations. It is also exposed along the Little Blue River Valley from Fairbury to a point due north of Gilead, and it extends up Big Sandy Creek to Alexandria. It outcrops in the vicinity of Diller, and a small area of it is exposed along the valley of a small stream about 3 miles southeast of Plymouth. The distribution of the formation is shown on the geologic map (Pl. II, p. 10) and some of its features are shown in Pl. IV, *A*.

BENTON GROUP.

MEMBERS REPRESENTED.

It has been shown by Mr. N. H. Darton that in southern Nebraska the formation formerly called Benton consists of three distinct members, which represent the Graneros shale, Greenhorn limestone, and Carlile shale of the Rocky Mountain region. Their combined thickness here is about 270 feet to the east and 650 feet or more to the west.

Generalized section of Benton group in southern Nebraska.

Formation.	Character of materials.	Thickness.
		Feet.
Niobrara	Chalkstone	
Benton:		
Carlile	Bluish, plastic clays containing a horizon of concretions near middle; iron pyrite and selenite crystals occur throughout the clay.	75
	Dark-colored shales and clays with thin beds of fossiliferous limestone, containing large numbers of *Ostrea congesta*.	75
Greenhorn	Limestone layers, cream colored and fine grained; they contain fish remains and are interbedded with light-colored, plastic clay.	1½
	Limestone layers interbedded with clay in strata of uniform thickness, containing *Inoceramus labiatus* in great abundance.	10
	Limestone layers, fine grained, light colored, interbedded with clay; darker, more impure, and porous below.	16
Graneros	Clay and shale, mostly dark gray, containing carbonaceous and sandy beds near middle.	70
Dakota	Sandstone and sandy shales	

GRANEROS SHALE.

Character and thickness.—The Graneros shale, or lowest division of the Benton group, consists in this region of dark-colored, plastic clays and shales. Near the middle of the formation occur beds of dark carbonaceous shale which closely resemble an impure variety of coal. Just below this shale and at the base of the formation the shales are usually sandy. Large sandstone concretions abound, some of which are fossiliferous. The shales contain a large amount of iron pyrite which, by weathering, changes to melanterite, a compound which readily dissolves in water.

In its outcrop area the thickness of the Graneros varies from 40 to 70 feet, but this amount probably increases to the north and west, for the formation has a thickness of 900 feet in the Black Hills region and over 200 feet in central Colorado. It lies conformably upon Dakota sandstone and is overlain in turn by harder beds of Greenhorn limestone. It is often difficult to sharply define the lower limits of the formation, owing to the similarity between the sandy shales at the base of the Graneros and those in the upper part of the underlying Dakota. The upper limit of the formation is clearly indicated by an abrupt change in the character of the sediments.

The following section indicates the character and succession of the beds near Fairbury:

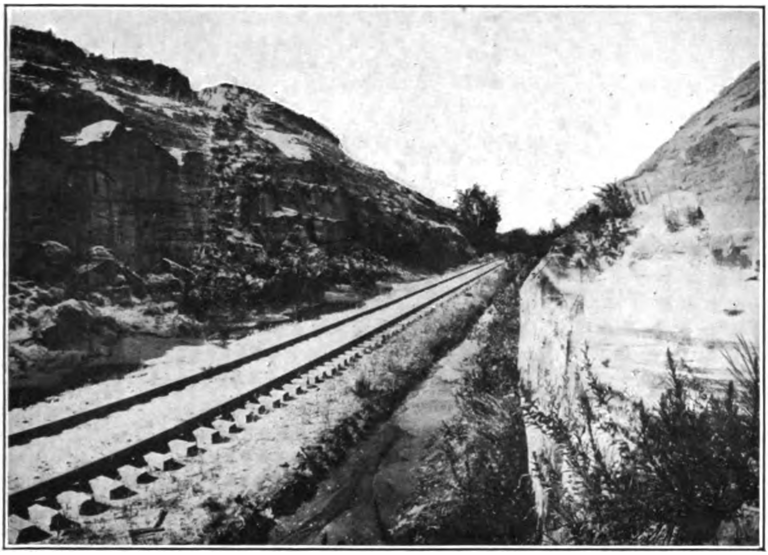
Section of Graneros shale and associated formations 5 miles northwest of Fairbury.

Formation.	Character of materials.	Thickness. Feet.
Greenhorn	Limestone alternating with beds of clay. The limestone contains *Inoceramus labiatus* in great abundance.	25
Graneros	Dark-colored shale and clay, containing thin beds of limestone	55
Dakota	Sandstone, medium grained, rust colored, with white and variegated clays below.	60

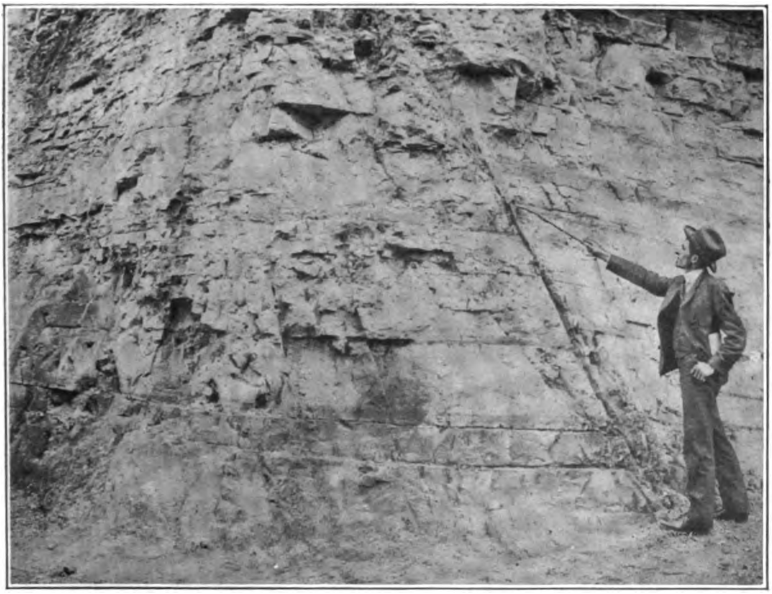
Exposures.—The Graneros shale is exposed in the eastern part of the district, mainly in Jefferson County, although exposures are found in Thayer County along Rose and Big Sandy creeks and Republican and Little Blue rivers. The most extensive exposures are in the bluffs south of Hubbell; in a small ravine on the north side of Little Blue River, southwest of Alexandria; and beneath the limestone capping slopes 4 or 5 miles northwest of Fairbury.

GREENHORN LIMESTONE.

Character and thickness.—The Greenhorn limestone, or middle formation of the Benton group, consists of limestones and clays in alternating succession. The limestones, which predominate, are soft,



A. DAKOTA SANDSTONE EAST OF ENDICOTT, NEBR.



B. NIOBRARA LIMESTONE NEAR NORTON, KANS., SHOWING SMALL FAULT.

light colored, and fine grained, and occur in beds ranging in thickness from 3 to 10 inches, the average being about 6 inches. They are usually fossiliferous, containing layers with many remains of *Inoceramus labiatus*, which is characteristic of the formation. The clays are light colored, plastic, and are in beds rarely exceeding a few inches in thickness.

The formation ranges from 25 to 30 feet thick and generally exhibits four limestone and clay members, which in regions to the south, owing to their distinctive characters, have been given local names by the Kansas geologists. The lowermost member, which in northern Kansas is a hard, dark-grayish limestone, is locally known there as the Lincoln marble. The individual beds of this member are about 8 inches thick and the total thickness is approximately 15 feet. Above the Lincoln marble there are several thin layers of white limestone interbedded with clay and having a total thickness of 10 feet, which are known as the Flagstone member. The next member consists of somewhat darker colored limestones containing many *Inocerami*, and for this reason it has been designated the *Inoceramus* member. It is 4 to 5 feet thick. The top member consists of one limestone layer about 9 inches thick, which has been called the Fencepost limestone owing to its extensive use for fence posts throughout the region.

These members of the Greenhorn formation are not so distinct in the region to which this report relates as they are in areas farther south, but they are all recognizable. In the excellent section south of Hubbell the lowermost division includes the equivalents of both the Lincoln marble and the Flagstone member, the middle division the *Inoceramus* member, and the uppermost division the Fencepost member. The *Inoceramus* member appears to be somewhat thicker in Nebraska than in Kansas. The Lincoln marble is well exposed in a cut bank along Little Blue River northwest of Gilead, where its thickness is about 15 feet.

The part of the Greenhorn limestone which is quarried appears as a light-colored streak high in the slopes in Jefferson County and in the lower parts of valleys in the eastern part of Thayer County. At a quarry 4 or 5 miles northwest of Fairbury the exposures are at an altitude of slightly less than 1,500 feet. Along the river north of Gilead the altitude of the formation is from 1,460 to 1,490 feet. Southwest of Endicott the base of the formation has an altitude of about 1,525 feet. The beds quarried south of Kesterson have an altitude of 1,535 feet, while at Hubbell they are at about 1,505 or 1,510 feet. Westward along Rose Creek Valley the beds gradually sink from high in the slope and reach the level of the valley bottom between Hubbell and Chester. These facts indicate that the formation dips gently to the northwest except for a small local flexure in the southern part of Jefferson County. Where present at the surface the limestones form a ridge or escarpment in the valley slopes, below which the underlying Graneros shale is marked by a clay slope.

Fossils.—*Inoceramus labiatus*, which characterizes this formation, occurs in large numbers in most of the beds. The formation has also yielded several specimens of fossil fish, and Dr. G. A. Birdsall, of Alexandria, has collected vertebræ and bones of various kinds from quarries north of Gilead. Mr. C. A. Carmony obtained, south of Kesterson, a large ammonite, which is now on exhibition in the State Museum of the University of Nebraska. The best specimens of fish remains are found in the fine-grained limestone layers near the top of the formation.

CARLILE SHALE.

Character and thickness.—The Carlile shale, the uppermost formation of the Benton group, consists of dark-colored clays and shales, which, in Kansas, have been separated into two members. The lower, which is the more calcareous, carrying thin beds of fossiliferous limestones, has in that State been designated the *Ostrea* horizon, on account of the presence of large numbers of *Ostrea congesta*, while the upper, which is composed of bluish, plastic clays, with fewer fossils, has there been designated the "*Septarian* zone" or Blue Hill beds. Near the middle of this upper member is a horizon of biscuit-shaped concretions, which is well exposed in the vicinity of Lovewell, Kans. These concretions are often traversed by cracks filled with calcite, selenite, and occasional crystals of barite. They are generally large, some exceeding 6 feet in diameter. Throughout the formation and especially in its upper part there are large quantities of iron pyrite, which decomposes to sulphate of iron, or melanterite, a mineral which appears on the surface as a light-colored powder of acrid taste. By chemical reaction the decomposing pyrite in the clay banks also forms calcium sulphate, which crystallizes as selenite, and crystals of this mineral are usually scattered over the surface in great abundance.

The exact thickness of the formation is believed to be over 200 feet in Nuckolls County and westward, but owing to erosion of its upper surface it thins out in Jefferson County along an eastern margin shown on the map (Pl. II).

Exposures.—The Carlile shale is not extensively exposed in the area included in this report, but it outcrops at intervals along the valleys of Republican and Little Blue rivers and Rose Creek. It usually appears on the slopes as a narrow band overlain by loess and resting upon greenhorn limestone. Along the south margin of the district it is exposed as an area of irregular width capping the higher land from a point nearly due south of Kesterson to near where Republican River crosses the State line.

NIOBRARA FORMATION.

Character and thickness.—The Niobrara formation in southern Nebraska consists principally of a chalky limestone known as chalk rock, with interbedded layers of calcareous clay and local deposits of flint. The prevailing colors of the rock are lead gray, light gray, and yellowish, depending on the degree of weathering. Much of the weathered rock is straw yellow, and in certain localities is ocherous in color; in the bluffs south of Guide Rock, where the weathered portions of the rock are rapidly removed by erosion, it is lead gray with a decided bluish tint. The chalk rock has a porous texture and gives a hollow sound when struck with a hammer. It has an uneven fracture and a tendency to break into splinter-like forms. It varies considerably in composition from place to place, the principal impurities being clay, silica, and gypsum. Where clay is present in large amounts the beds are usually shaly.

In previous descriptions of the geology of this portion of Nebraska, no subdivisions were made of the Niobrara formation, which was described as consisting mainly of soft limestone chalk rock, or limy clays, presenting considerable variation from place to place. It has been found, however, that it comprises two distinct members, a lower and an upper, which are probably equivalent, respectively, to the Fort Hays beds and the Smoky Hill chalk of Kansas. The total thickness is about 400 feet. Some features of the formation are shown in Pls. IV, *B*, and VIII, *A*.

The basal member of the Niobrara consists of massive soft chalky limestones, bluish to light gray on freshly broken surfaces, but weathering to yellowish. The thickness of this member varies from 40 to 50 feet and the outcrops are usually marked by more or less prominent ledges capping the softer shales of the underlying Carlile formation. Extensive exposures of these beds occur on the south side of Republican River between Superior and Bostwick, and along Whiterock Creek in Kansas.

In southern Nebraska the upper member of the Niobrara formation is about 300 feet thick. It consists of a bluish-gray chalk, generally massive and irregularly jointed, with layers of light-colored limestone and calcareous clays distributed throughout. The beds in the upper part vary considerably in character in different localities. Wherever the formation is overlain by Pierre shale the chalky beds continue to the top of the formation, but in a wide area in the vicinity of Cambridge, and in the southern part of Nuckolls County, where the Pierre is absent, the upper beds of the Niobrara are ocherous and more or less flinty. The flint is brownish, reddish, or greenish in color; it occurs in continuous beds in the top of the formation, but lower down in scattered nodules; the beds vary in thickness from a few inches to 10 feet, and it is believed that they have accumulated in the chalk subsequent to its deposition, probably during late Tertiary or Quaternary times.

Fossils.—Fossils are very abundant in the Niobrara formation. *Ostrea congesta* and a large flat *Inoceramus* are the most common forms, the former often attached to fragments of the latter. Well-preserved fish remains are not infrequent, and turtles have been collected in the vicinity of Cambridge. The chalk rock, when examined closely, is found to be composed largely of minute shells which grade in size from those plainly visible to the unaided eye to microscopic forms.

Distribution.—The Niobrara formation has a relatively wide outcrop area in central-southern Nebraska. It first appears under the loess in isolated areas in the valley of Little Blue River and its tributaries above Angus, at Nelson in the central part of Nuckolls County, and farther south on either side of Smyrna and near Bostwick. The formation outcrops most extensively along Republican River and its tributaries, rising high on the slopes south of Guide Rock. Westward it gradually falls to lower levels on the slopes, until, in the vicinity of Republican, its exposures are principally limited to the lowlands of the valley. At Edison the Niobrara outcrops narrow somewhat, and the Pierre shale occupies a portion of the bottom lands on either side, but to the west it widens again, retaining a nearly uniform width to the point where it passes beneath the Pierre shale south of Indianola. In the low valley land along Republican River the Niobrara formation is generally covered by Quaternary deposits. At Riverton, Republican, and south of Orleans the alluvial deposits have been removed, exposing the chalk rock in the banks of the river. The Niobrara occupies the lowlands of Beaver Creek Valley from its mouth westward to near Danbury, and along Sappa Creek, its main tributary, to beyond the Nebraska-Kansas State line, but it is nearly always covered by a thin deposit of alluvium. The eastern margin of the formation under the loess is near the east line of Nuckolls County. The details of the distribution of this formation are shown on the geologic map, Pl. II.

PIERRE SHALE.

Character and thickness.—The Pierre shale, as exposed along the Republican Valley in southern Nebraska, consists mainly of plastic, loose-textured, carbonaceous clays which become shaly on weathered surfaces. The clays are unctuous when moist and hence are popularly known as soapstone. The common colors are dark bluish to black, with many rust-colored spots. Gypsum crystals are distributed throughout the shales, weathering out in great abundance on the barren slopes, and iron pyrites are found in thin layers at many horizons. The pyrite decomposes readily, and much of the resulting product is scattered over the surface as irregular fragments of iron oxide. The maximum thickness which the formation reaches in the western part of Dundy County is not known, but apparently it is more than 1,000 feet. No reliable well records could be obtained to show the thickness underground, but the formation is known to thicken rapidly to the west and north, reaching 7,700 feet west of Denver. In the syncline between Arapahoe and Naponee it has a thickness of 50 feet or more and thins out to the east and the west. A well-defined layer in the Pierre shale in this region consists of a carbonaceous shale resembling an impure coal in some respects. This layer has a thickness of about 25 feet, and is well exhibited along the Republican from near the Alma bridge to beyond Orleans. The shales of this member are least plastic near the top and erosion often develops buttresses and recesses in them. The bedding and jointing are fairly distinct, and many layers and joint seams contain gypsum as a yellowish powder. Overlying this carbonaceous member are dark-bluish clays, with well-defined bedding, but fewer joints. In Dundy County the upper part of the exposed Pierre for 10 to 12 feet are of yellowish color. The Pierre shale contains a few fossils, such as *Baculites compressus* and small ammonites.

Distribution.—The Pierre shale rests conformably on the Niobrara and is overlain unconformably by Tertiary deposits (see Pl. V, *B*). It is exposed along the Republican and its tributaries from the western part of Franklin County to the vicinity of Arapahoe, and from near Indianola to the west line of the State. It also extends for some distance up Prairiedog Creek to beyond the Nebraska-Kansas line, and up Sappa and Beaver creeks into the eastern margin of Furnas County. It reappears in the valley of Sappa Creek a short distance above Lebanon and continues to beyond the State line.

TERTIARY SYSTEM.

The Tertiary deposits of southwestern Nebraska appear to belong entirely to the later epoch of that system but they have not as yet been definitely classified. Apparently the principal formation corresponds to the Ogalalla of Darton, but possibly to some of the Arikaree as well.

Character and thickness.—The Tertiary deposits consist mainly of sand, gravel, and clay, in places bound together by calcareous cement into beds of variable hardness. Their character varies greatly from place to place. The sands are mostly medium to fine grained, often grading into a coarse cross-bedded sand and gravel. The gravel is waterworn and varies in size from small pebbles to bowlders 4 to 6 inches in diameter. (See Pls. V, *C*, and VI, *B*.) The materials comprise quartz, feldspar, granite, andesite, and porphyry, apparently derived from the Rocky Mountins. The clays are usually sandy, sometimes becoming so fine grained as to be a silt or loam. Deposits of this character occur north of Max, where there is much clay or loess-like silt, but in general the greater part of the sediment consists of sand and gravel irregularly mixed and often imperfectly stratified. Volcanic ash is generally associated with the sand beds and it occurs in lens-shaped deposits or beds in a number of places. The usual color of the ash is light gray and it is medium to fine grained. Opalized wood is scattered over the surface at various places in the Tertiary outcrop, notable localities being southeast of Laird and at the head of Rock Creek. At a few places in the western counties the calcareous cement occurs in sufficient amount for use as a natural plaster. A partial section of the Tertiary beds, as exhibited southeast of Franklin (see Pl. V, *A*), is given below:

Section at Lookout Mountain southeast of Franklin, Nebr.

	Feet.
Limy sand rock, texture varying; color gray to white	10
Sand, light colored on surface, fine grained, at places lithified	10
Quartzite, light to olive-green color; texture variable, but usually medium grained; siliceous cement	1½
Sand of various colors and medium grained	30
Chalk rock (Niobrara); colors, yellowish at top, whitish and bluish gray below	200
	251½

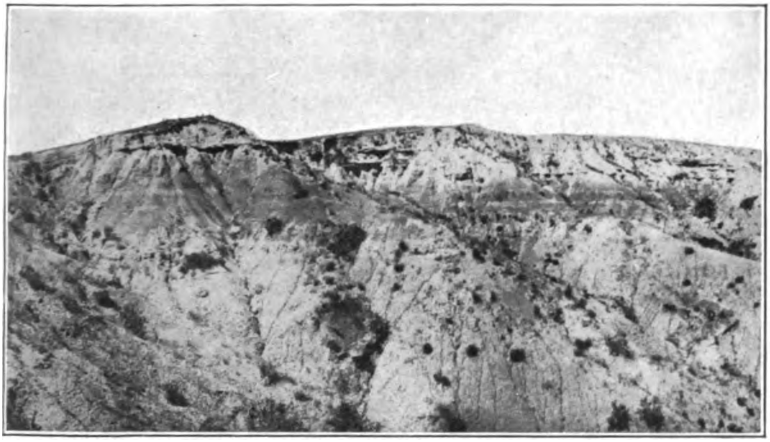
Distribution.—The Tertiary deposits are exposed along the south side of Republican Valley from a point south of Red Cloud to Edison, and thence westward to the Nebraska-Colorado line along both sides of the valleys of the Republican and its principal tributaries. They are also exposed along Beaver and Sappa creeks and their numerous small branches throughout their entire extent within the area. The formation lies on the uneven surface of the Pierre (see Pl. V, *B*) and Niobrara formations, and is in turn extensively overlain by loess and other Quaternary deposits.

QUATERNARY SYSTEM.

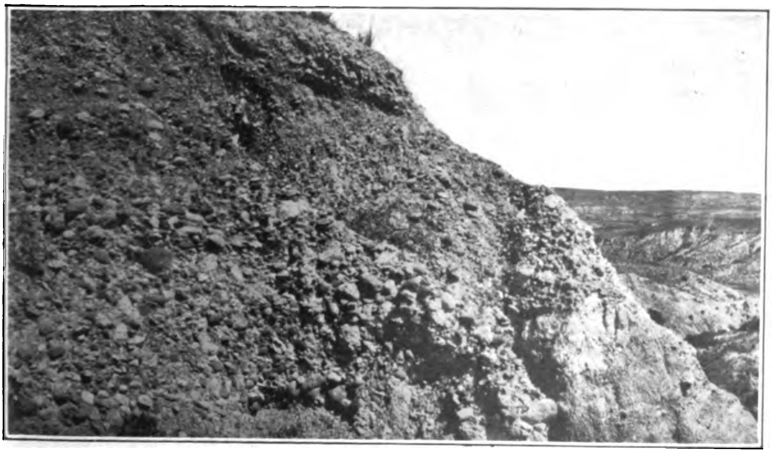
DRIFT.

The greater part of Nebraska is covered by a thin but widespread sheet of sands and gravels, transported to the region by glaciers from the north and by streams from the west during Pleistocene

A. LOOKOUT MOUNTAIN, SOUTHEAST OF FRANKLIN, NEBR., SHOWING BLUFFS CAPPED BY TERTIARY SANDY LIME ROCK.



B. TERTIARY "MORTAR BEDS" ON PIERRE SHALE EAST OF HAIGLER, NEBR.



C. TERTIARY GRAVEL NEAR HEAD OF TRAIL CANYON, DUNDY COUNTY, NEBR.

time. The glacial deposits have been called northern or glacial drift, and the stream deposits western drift. The glacial drift occurs only in the eastern part of the region treated in this report—that is, in Jefferson County and the eastern part of Thayer County—but it extends north across eastern Nebraska. The greater part of the material is till with scattered deposits of bowlders, and it is more or less overlain by loess, especially to the west, where its margin is hidden by the loess. The sands and gravels of western origin extend westward under the loess, and in Jefferson County, especially along the Little Blue, appear to merge into the glacial drift, but the contact relations are not clearly exposed.

The glacial drift in Jefferson and Thayer counties lies unconformably on the Dakota, Graneros, Greenhorn, and Carlile formations, and in places, especially on the uplands, is covered by loess. The glacial sands and gravels at Fairbury appear to be older than much of the clayey till in eastern Nebraska. They are separable at places into two members, an upper rusty-colored one and an underlying lighter colored and locally more regularly stratified member. These two show best in the sandpit of the Rock Island Railroad, about 4 or 5 miles northwest of Fairbury. Bowlders and pebbles occur in both divisions, but they are more noticeable in the upper one, perhaps because this is the more exposed and eroded.

A thin bed of brownish to yellowish clay till caps the glacial sands in the uplands about Fairbury, coming as low as 1,370 feet in altitude, but usually not much below the 1,380-foot level. It increases in thickness eastward in the direction of Jansen, Plymouth, and Lincoln. This clay contains pebbles and bowlders, usually of pinkish quartzite. It rises to an altitude of 1,430 feet 1 mile northeast of Jansen and to about 1,400 feet in the vicinity of the Chicago and Rock Island Railroad bridge across Cub Creek, at which place about 40 feet are exposed. In a railroad cut just west of this bridge the till is separable into two divisions. The lower, 12 feet of which rise above the level of the track, is sandy and concretionary, with few pebbles and bowlders; of the upper, about 11 feet of typical yellowish, pebbly, and bowldery clay are exposed in the cut, and it rises still higher in the hill slope. This member of the drift is distinct from the loess, by which it is covered to a depth of 30 to 45 feet at Plymouth.

Concretions often occurring in the till are composed of calcium carbonate. They range from 1 inch to more than 4 inches in diameter.

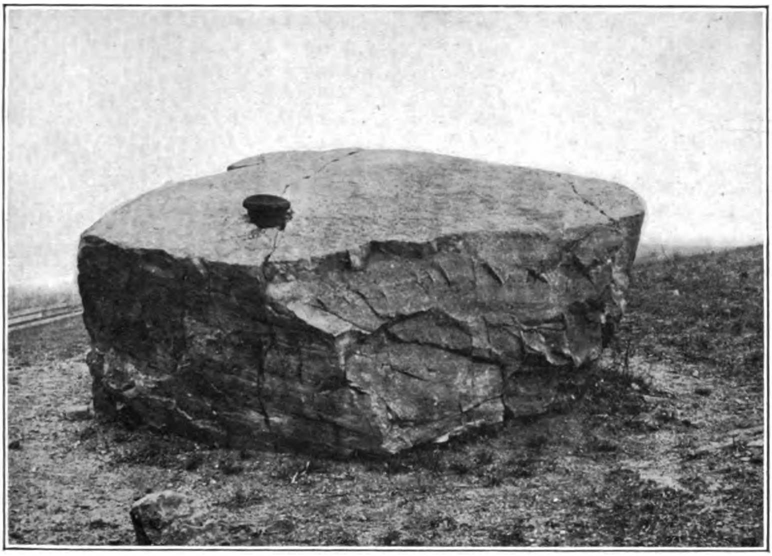
In general, there are two fairly distinct members of the glacial drift in Jefferson County, as shown by a section between Fairbury and Plymouth, both containing bowlders and both showing smaller local divisions. Small deposits of clay have been observed to occur in the sand and gravel. Clay which may prove to be of glacial origin is found along the Chicago and Rock Island Railroad southwest of Thompson, and even as far west as Nelson.

The vertical range of glacial bowlders and till is from altitudes of 1,250 to over 1,500 feet. The exposed bowlders are confined to Jefferson County, with a few in Thayer County. They occur for the most part east of Little Blue River, but extend 2 to 4 miles west of that river, between Powell and Steele, and to only a few miles south of Rose Creek. They come to the surface where the loess and finer parts of the till are eroded, and in some places they become abundant. The largest area of this kind is located just southeast of Endicott, where bowlders, mostly of Sioux quartzite, with a relatively small number of granite, cover nearly 2 square miles of the Dakota escarpment and adjoining slopes (see Pl. VI, *B*). These bowlders have been concentrated from till by the removal of the sand and loam by erosion. In the greater part of Jefferson County east of the river bowlders usually occur beneath the loess cap, and where the loess has been eroded the bowlders and other coarser glacial materials are brought to view. Other bowlder areas occur near Steele, Fairbury, and at a number of places in Cub Creek Valley. A large quartzite bowlder northeast of Fairbury, 4½ by 9 by 10 feet in size, is shown in Pl. VI, *A*. Another of coarse-grained granite, 4½ by 6¾ by 17 feet in size, is located in a gravel bench one-half mile away; its size has been reduced by blasting. The glacial bowlders comprise Sioux quartzite, granites, syenites, gneiss, hornblendic and mica schists, flinty limestone, Dakota sandstone, and Greenhorn limestone. Some of these were carried long distances by ice, while others came from ledges not distant. The granitoid rocks are rounded in part by weathering, but most of the quartzites are angular and little worn.

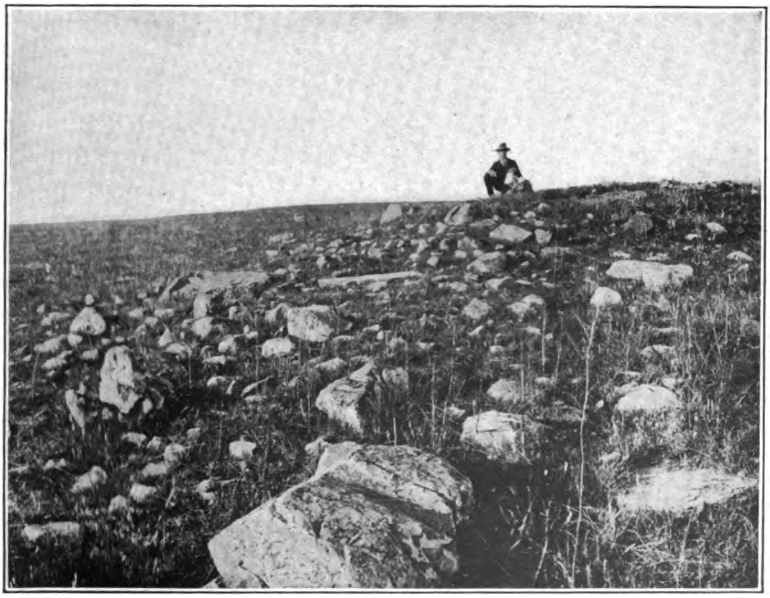
It appears that the presence of the ice sheet in Jefferson County affected the drainage over wide areas westward, causing the rivers to fill up their valleys and then to spread sediment over the general region along and to the west of the glaciers. The deposits of western drift are found as far west as Arapahoe, Cambridge, and Trenton. That this deposit is of western origin is proved by the presence of a large amount of typical Rocky Mountain rock. Much of it, however, came from Tertiary formations which were derived from the Rocky Mountain region.

Remains of the primitive elephant have been found in the Fairbury gravels.

All of the glacial drift in the region treated in this report is generally known as the Kansan drift. A part of it may be of Aftonian age.



A. QUARTZITE BOWLDER NORTHEAST OF FAIRBURY, NEBR.



B. GLACIAL BOWLDERS SOUTHEAST OF ENDICOTT, NEBR.

LOESS.

This formation constitutes the surface of the greater part of southeastern Nebraska and adjoining regions. Originally it covered the entire surface, but it has been cut through by the larger streams and now remains on the wide plateau areas between the valleys. The typical loess is characterized by its fine, even-grained, massive structure, porous texture, light-buff color, and the presence of a weak calcareous cement. It is often called the "bluff" deposit where deep canyons and river bluffs are formed of it, because, owing to its massive structure, it weathers into steep slopes. The well drillers speak of it as "yellow clay." The loess generally lies directly upon glacial drift or the western gravel deposits, but also overlaps on the older formations. Its thickness on the high loess plains is about 100 feet. The formation has a strong tendency to vertical displacement in canyon walls and bluffs, so that on many slopes it settles or creeps over the edges of the underlying formations, concealing them from view. Where eroded by running water it stands in nearly vertical banks. On account of its massive structure and coherent nature, many wells bored in the loess region do not require casing in the part penetrating this formation. Ordinarily cellars in loess do not require to be walled.

The loess varies noticeably in color and somewhat in texture in different parts of the region, varying from light buff to brownish, a difference apparently related to the underlying beds, for the color is lightest where the loess overlies the light-colored Niobrara chalk rock and darkest when on or near the ocherous Niobrara and the Dakota formation.

The loess consists principally of silt and clay particles loosely cemented by carbonate of lime and stained by a small amount of iron oxide. The proportion of each of these ingredients varies from place to place. The silt grains increase in size and proportionate amount from east to west and apparently also with depth. The upper surface of the loess is darkened by humus and grades into the cultivable soil.

The mode of accumulation of the loess has been a subject of much discussion. According to the earlier view it is a wind-blown deposit, while according to a later view it was deposited over a wide extent of country by low-grade streams at the close of the Pleistocene; probably both of these agencies have been factors in its origin.

It contains numerous fossil shells, mostly gasteropods, of freshwater nature.

TERRACE DEPOSITS.

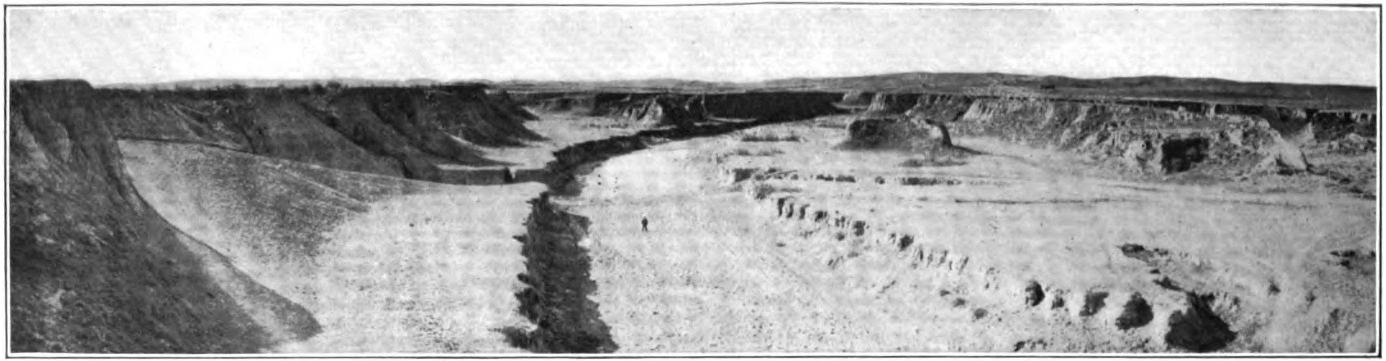
Terraces are conspicuous along Republican River and Beaver, Sappa, and Prairiedog creeks. They are locally known as benches, or as second and third bottom lands. Their heights in the Republican Valley are mostly 6 to 14, 25 to 40, and from 60 to 80 feet above the first bottom. Low benches are clearly defined in the vicinity of Haigler. At Oxford they are from 6 to 8 feet high. The terrace extending along the south side of Republican River from Amboy to a point southwest of Superior is 25 to 30 feet high. Four miles west of Benkelman a high terrace rises about 75 feet above the river. At several places in Dundy County and in the western part of Hitchcock County the wind has eroded the terraces into dune-sand topography, as illustrated in Pl. VII, *B*. Terraces on the south side of Republican River are less continuous than those on the north, owing mainly to the fact that the river crowds the right bank at places and has entirely removed the benches.

The terraces are capped by an alluvial deposit resembling somewhat the loess in texture, but showing more definite stratification and greater variation in the size of the component parts. The material in the high terraces in Dundy and Hitchcock contains a large amount of silt and in many respects resembles the loess to the west. It contains remains of the primitive elephant and the mastodon. Bones of *Elephas primigenius* were found by Mr. Max in the terrace deposits just north of the town of Max; other remains of this species have also been collected from these beds along Driftwood Creek 12 miles south of Trenton and at several other localities in the region.

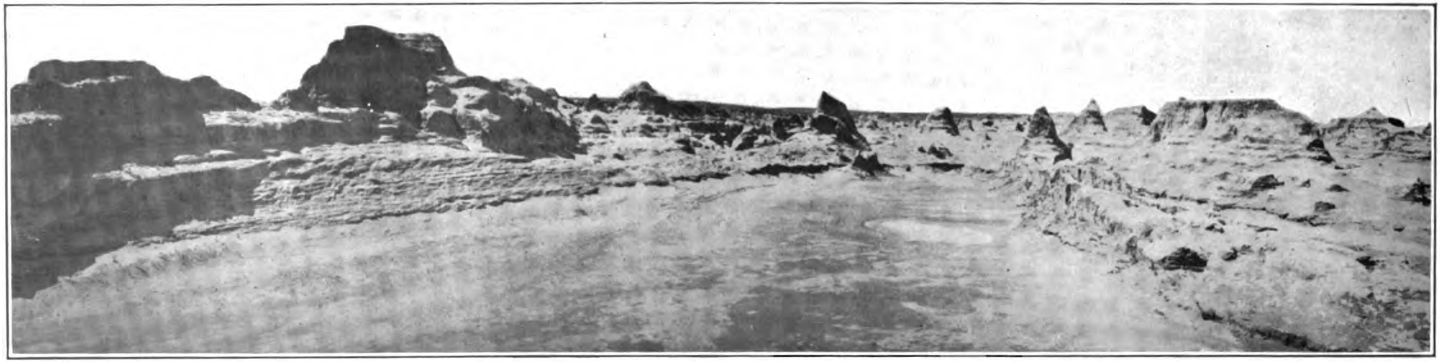
ALLUVIUM.

A relatively thick deposit of alluvium occupies the floors of all the principal valleys and their tributaries throughout this portion of Nebraska. It generally consists of sand, gravel, and clay which shows considerable variation in character in different parts of the region.

The thickness of the deposit varies from 20 to 80 feet, the average being about 50 feet. The broader areas of alluvium are composed of fine sand near the surface, with medium to coarse gravel below, and in most localities beds of clay of variable thickness have been encountered by well drillers. Along the smaller tributaries the alluvium varies greatly in amount and character, according to the nature of the formations from which the material is supplied. The smaller streams traversing Tertiary, Dakota, or Pleistocene formations usually contain much alluvial sand and gravel, while those flowing over only Niobrara and Benton formations have but little alluvium along their course, for the materials, being fine-grained, are usually transported at flood times to the larger stream courses, leaving the bed rock uncovered. At Fairbury, along Little Blue River, the alluvial bottom land is from ½ to 2 miles in width. The depth of the deposit is not definitely known, but it has been penetrated to reported depths



A. TERRACES NEAR MOUTH OF TRAIL CREEK, DUNDY COUNTY, NEBR.



B. WIND EROSION IN HIGH TERRACE WEST OF BENKELMAN, NEBR.

of 60 to 80 feet. In this region it is composed of medium to coarse sand, gravel, and clay, with a small proportion of decomposed organic matter.

DUNE SANDS.

In the western part of Dundy County, northeast of Haigler, the Tertiary sands have been blown by winds into hills and ridges, with intervening dry valleys and basins forming a typical sand-hill region, as shown in Pl. VIII, *B*. In some places along the Republican, as far east as Trenton, the high, silty terrace has been more or less eroded by the wind, forming blow-outs and dunes. In places the dune sands are encroaching on the river. The veneer of sand is thin, and has been largely derived from the Tertiary materials and high-terrace deposits. Small terrace dunes are also found along the sandy bottoms of Little Blue River near Fairbury and at numerous places along the Republican.

ECONOMIC GEOLOGY.

MINERAL RESOURCES

The region to which this report relates possesses various mineral resources, some of which are sufficiently valuable to warrant development.

COAL.

Prospecting for coal has been in progress throughout the region since the time of earliest settlement. Three carbonaceous horizons, each in a different formation, have seemed promising to prospectors.

The first is in the upper part of the Dakota formation, where thin beds of impure lignite occur. During 1903 a small amount of this coal was mined three-quarters mile east of Powell, Jefferson County. The thickest bed at this place is about 7 inches and it outcrops in a ravine north of Little Blue River. Thin beds of lignite probably occur in many parts of the Dakota formation throughout the region, but there are few outcrops, and it is doubtful if the material ever reaches a workable thickness. Coal is mined to some extent from the Dakota formation at a few localities in Kansas, south of Thayer and Nuckolls counties, and the same amount and quality of coal that is worked in Jewel County, Kans., is believed to extend to the vicinity of Hardy and Superior, Nebr., but the depth at which it would be reached then entirely precludes the possibility of working it successfully.

The second carbonaceous horizon lies above the Dakota in the Graneros shale, the lowest division of the Benton group. The rock of this horizon outcrops at several places in Jefferson County, where it has been prospected extensively, but without success.

The third carbonaceous horizon referred to is in the lower part of the Pierre shale. It has been prospected more or less in the region between Republican and Arapahoe, also south and west of Orleans, but offers no encouragement whatever of affording true coal or lignite.

PETROLEUM AND NATURAL GAS.

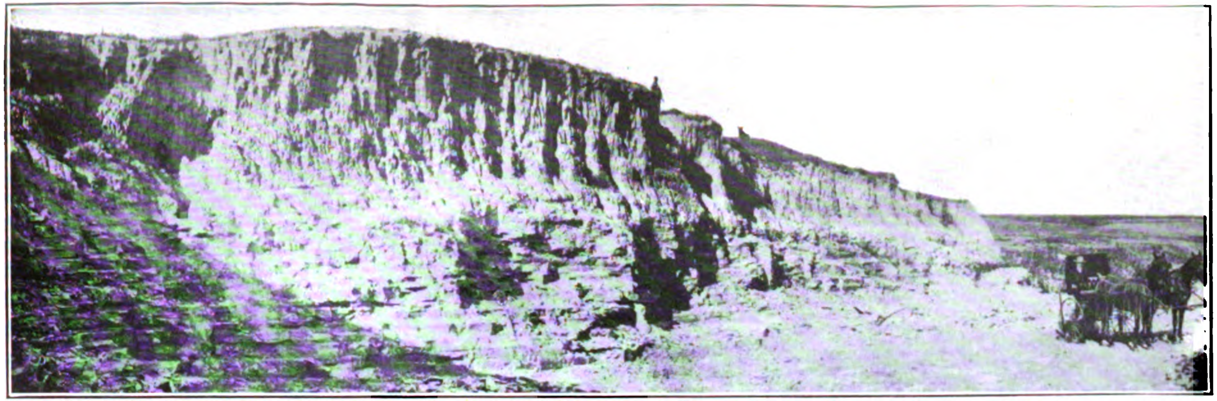
While there are no grounds for believing that petroleum and gas may be obtained by borings in the Republican Valley region, these materials may possibly occur, and the possibilities are such as to warrant more complete and detailed investigation. There are no surface indications of oil and the only gas reported is a small amount in a well 405 feet deep at McCook. This well yields a flow sufficient to afford a flame that flashes up from a cap on the casing and burns more strongly than an ordinary gas jet. The engineer at the pumping station where the well is located stated that enough gas collects in the cap to burn about one-half hour.

The presence, discovered by Mr. Darton several years ago, of an anticlinal arch in Furnas County, has excited much interest in its relation to the possible occurrence of oil or gas, and plans have been made for drilling for these products. The crest of this arch extends down Medicine Creek through Cambridge and southeastward across Furnas County, and if oil or gas are present underground they might be expected along that line. There is, however, no evidence whatever that the region is underlain by rocks containing oil or gas. The Dakota sandstone, which lies about 700 feet below the river at Cambridge has never yielded oil, and probably at a depth of about 1,000 feet it is underlain by red beds, which are nonproductive; the thickness of the latter is unknown, but probably it is over 500 feet. The red beds are underlain by limestone and shale, which might possibly yield some products of value; the depth of these increases rapidly to the west and to the east of the arch.

The Carboniferous rocks which carry oil and gas in southeastern Kansas extend under south-central Nebraska, but several deep wells which have penetrated these rocks in northern Kansas found no oil. The Dakota formation under the Republican Valley carries artesian water under heavy pressure, a condition which would prevent the accumulation of oil or gas. The oil of eastern Colorado is obtained from sandy beds in the Pierre shale, and possibly such beds may be found in the formation in Hitchcock and Dundy counties.

BUILDING STONE.

Building stone is quarried at many points in the Republican Valley. The Dakota sandstone, though more or less friable and not of pleas-



A. NIOBRARA LIMESTONE QUARRY NORTHEAST OF CAMBRIDGE, NEBR.

B. TYPICAL SAND HILLS NORTHEAST OF HAIGLER, NEBR.

ing color, is quarried southeast of Endicott and southeast of Kesterson. This material is used mainly for foundations and culverts in Fairbury, Endicott, and Steele. A thin bed of compact sandstone is found in the Dakota formation about 2 miles northwest of Fairbury, which closely resembles quartzite, and a hard sandstone similar in character occurs near Junction, but neither of these is sufficiently extensive to be valuable. The Greenhorn limestone has been quarried for twenty years in the vicinity of Hubbell, and although the present output is only about 40 cars per year it formerly exceeded 200 cars. Most of this stone is now used in the northern part of Kansas. A line of small quarries extends along the hill slopes wherever the Greenhorn formation is exposed. The principal quarries of this rock within this region are located about 5 miles northwest of Fairbury, a few miles northeast of Gladstone, north of Gilead, south of Kesterson, and in the vicinity of Hubbell. Most of the stone is obtained from the so-called Fencepost member, and other beds are worked locally. The product is used principally in building foundations, culverts, and sidewalks. The Greenhorn limestone is used for structural purposes throughout Jefferson, Thayer, and Nuckolls counties. It has been burned successfully to lime northwest of Fairbury.

The Niobrara chalk rock, though soft, has been quarried for building purposes along the Republican, between Superior and Alma. It is easily dressed and its color is not objectionable. The lower member of the formation has been less extensively quarried in Nebraska than in Kansas, where it is crushed at Montrose and used for ballast along the Chicago, Rock Island, and Pacific Railway. At Alma the upper beds of the Niobrara have been used for street pavements. The chalk packs firmly, sheds water, and wears well. In the vicinity of Cambridge, flinty beds of the Niobrara are quarried for building purposes. The A. Brown quarry (Pl. VIII, *A*), 2½ miles northeast of Cambridge, has been worked for twenty years. This flint extends over a wide area in the vicinity of the anticline both in Nebraska and in Kansas, and it might be used as a railroad ballast.

The Tertiary "mortar beds" afford stone suitable for foundation purposes in every county west of Harlan. The so-called "granite" at Woodruff is a compact sandstone, or quartzite occurring in the Tertiary. It is quarried and crushed for railroad ballast and concrete at the Atwood Company's quarry, about 2 miles west of Woodruff, Kans., and about one-fourth mile south of the State line. The stone is very hard, usually olive green in color and fine to medium grained, but the color and texture show some variation. The beds quarried range from 6 to 12 feet in thickness. Stone of this horizon occurs in the vicinity of Lookout Mountain southeast of Franklin, Nebr., where large blocks appear on the slopes of the hill. A ledge of rock of somewhat similar nature but of finer texture outcrops at places along Republican River in Furnas and Redwillow counties. It is 3 to 4 feet thick, and best exposed south of the river between Bartlett and Indianola.

CEMENT.

Portland cement is largely manufactured from limestone or chalk mixed with the proper proportion of clay or shale. These materials are ground, thoroughly mixed together and burned, and then reground. The Niobrara chalk rock and the Pierre shale are used in the manufacture of cement at Yankton, S. Dak., and these same formations outcrop along the Republican, where probably they could be utilized for that purpose. Unfortunately, in the area in which the chalk rock is most favorably exposed, it is not overlain by the clay, but large supplies of this ingredient could be obtained at no great distance. Other important factors to be considered in the production of cement, aside from the materials used, are fuel and water supply, but the conditions for these are as favorable in Republican Valley as in some other places where cement is profitably produced.

CLAY.

The Dakota formation contains extensive beds of high-class clays near Fairbury, Endicott, and Steele. Southeast of Steele the middle member of the formation is composed of light-colored to mottled clays, which appear over an area of several square miles, in slopes rising from the level of the river to an altitude of 1,325 feet. Between Steele and Endicott there is a clay pit from which the product is shipped to Hastings and Beatrice for use in the manufacture of brick and tiling. An abandoned pit near Endicott, which was worked out by a Beatrice firm a few years ago, afforded over 1,000 cars of clay for use in the manufacture of brick, pottery, and tiling. Clays of the Dakota formation produce very fine grades of brick and on that account will doubtless be more extensively used. Unfortunately there are no large towns near the outcrop areas, and the haulage to Lincoln and other principal cities of Nebraska is long and expensive. There are brickyards in most counties of the region manufacturing brick from either Dakota clay, loess, or alluvium. The principal yards are at Fairbury, Hebron, Deshler, Nelson, Alma, Beaver City, and Arapahoe.

SAND AND GRAVEL.

Some of the deposits of sand and gravel in the Republican Valley will eventually prove to be valuable. The sand is extensively distributed while the gravel is of less common occurrence. Most sandpits are operated for local use, yet a few ship to towns some distance away.

The sands and gravels worked come from the Dakota formation and from Tertiary, glacial, and alluvial deposits, the last two being the most important sources. The Dakota formation contains friable sandstone, which at places afford a small supply of sand. The Tertiary sands are mostly fine grained, but the gravels are locally coarse enough for use as railroad ballast. It is from the stratified deposits formed during the Pleistocene that most of the sand and gravel is obtained. The principal materials are of western origin and outcrop along Little Blue and Republican rivers. Along the former they are intermixed somewhat with materials of glacial origin and are coarser than the deposits farther west. The main center for sand and gravel is Fairbury, but the deposits extend far westward and are worked at or near Superior, Red Cloud, Beaver, Arapahoe, Cambridge, Trenton, and beyond. The sands usually lie in an accessible position just below the loess. There is an inexhaustible supply of coarse sand and fine gravel about Kesterson, Fairbury Junction, Helvey, Powell, and Hebron. The lower surface in Jefferson County is very irregular, resting on the eroded upper surface of older formations. In places the sand is not overlain by loess and at such places very little or no stripping is necessary. Where railroad facilities are favorable the expense of production is low.

The other principal source of sand is the alluvial deposits. The sand in the Republican bottom lands averages too fine for plaster, but might be used as a filler for concrete work and it may yet prove to be adapted to the production of sand-lime brick. Where the deposits along the streams have been derived from near-by glacial sands they have not changed greatly in character, but remain coarse enough for building purposes. This is the case in the deeper parts of the flood plain from Alexandria to Fairbury. The sands along the river at Fairbury are reported more than 80 feet thick at places. In the vicinity of Bostwick a small ravine contains much coarse sand derived from a bed beneath the loess and this sand is used locally for plaster. In many localities there are sand deposits under the loess, but they are not often well exposed.

Sandpits are found in the vicinity of nearly all towns. The largest shipments are from the Chicago, Rock Island and Pacific Railway sandpit, located northwest of Fairbury on a switch of the Nelson Branch. An old pit on a switch of the Chicago, Burlington and Quincy Railroad just west of Kesterson has afforded thousands of tons during the many years in which it has been worked. The St. Joseph and Grand Island Railway ships from a pit about midway between Endicott and Steele.

The sand of the various pits is used principally for plaster, masonry construction, ballast, and in the manufacture of artificial stone. The demand for it is increasing for each purpose named, especially the last. Artificial stone plants are operating now in most of the larger towns where a supply of sand can be had within a few miles as at Fairbury, Hebron, Superior, Nelson, Red Cloud, Cambridge, and McCook. The product is becoming not only a rival of natural stone but of brick as well.

VOLCANIC ASH.

Volcanic ash is a light-colored powdery deposit of volcanic origin. It is thought to have been thrown into the air by volcanoes in the mountains and carried far eastward by the wind, and in some cases to have been again taken up later and redeposited by water. It is composed of hard, angular fragments of volcanic glass resembling pulverized pumice, and occurs as thin beds and irregular pockets in the Tertiary formations. The thickest beds are in Furnas and Harlan counties.

Mr. S. C. Zike formerly hauled and shipped from a pit 5 miles south of Edison from an opening now 30 feet high and over 100 feet long. The ash was shipped to some of the larger eastern cities. Mr. J. C. Gay of Orleans is shipping the ash from that town under the name of silica. The product goes principally to Europe and is used as an abrasive and in the manufacture of sapolio.

The following analysis of Harlan County ash by Mr. R. S. Hiltner gives the chemical composition:

Analysis of volcanic ash from Harlan County.

	Per cent
Silica (SiO_2)	71.56
Iron oxide and alumina (Fe_2O_3 and Al_2O_3)	15.04
Calcium oxide (CaO)	1.19
Magnesium oxide (MgO)	.49
Sodium and potassium oxides (Na_2O and K_2O)	5.51
Sulphuric anhydride (SO_3)	.73
Loss on ignition	5.48
	100

OCHER.

Two formations carry ocher (hydrated oxide of iron), which is used to a limited extent for paints. The Dakota clays east of Endicott, and in secs. 19, 24, and 30, T. 1, R. 3 E., southeast of Kesterson, contain a large admixture of reddish and yellowish ocher. In the last-named locality the yellowish to reddish deposits extend onto a number of slopes in that vicinity.

Portions of the Niobrara formation are ocherous in much of Franklin and Webster counties, and also on the anticlinal fold farther west, where the Pierre clay has been removed by erosion. At Indianola paints are manufactured from the weathered upper surface of the Niobrara at a level of 30 feet below the town. The bed is 11 feet thick at a shaft in the western part of the town, and thins out southward. The ocher was mined about twelve years ago; the shaft has been reopened recently by Adolph Smith and J. P. Reiter, who have installed a mill and are now placing several grades of the product on the market.

WATER RESOURCES.

On account of their economic importance and their close relation to public health the water resources, especially the underground water of this region have been given special consideration. The principal water supplies are obtained from wells, springs, streams, and lakes or ponds. These may be classified as surface and underground waters.

SURFACE WATERS.

GENERAL CHARACTER.

The surface waters in this region are products of local rainfall in a catchment area but very slightly larger than the district to which this report relates. The amount of direct run-off in any region depends on the quantity and nature of the rainfall, the texture of the soil, and the drainage conditions, the maximum amount being where steep slopes prevail and the soil is fine textured. The run-off in this district is largest in the rougher parts of the central counties and eastward, where the rainfall is greater and the fine-grained loess soil covers most of the surface, the minimum amount being lost where the soil is open textured and the land not surface drained. In the sandhill region and in most of the Tertiary area the direct run-off is small and much water is absorbed; the rainfall is light and the soil is very porous.

In certain canyons heading high in the table-lands the run-off is large, especially after a hard, driving rain. Train Canyon, for example, has bare clay slopes, great declivity, no springs, and never carries water except after what is called a waterspout. At such times water fills the canyon and flows out into the Republican Valley with force sufficient to deflect the river temporarily across its flood plain. The railroad bridge across the lower course of the canyon has been damaged by this rush of water.

REPUBLICAN RIVER.

Republican River heads in the table-lands of eastern Colorado many miles east of the Rocky Mountains, and, entering Nebraska in the southwestern corner of Dundy County, flows east about 250 miles across that State before it turns south into Kansas, near Superior.

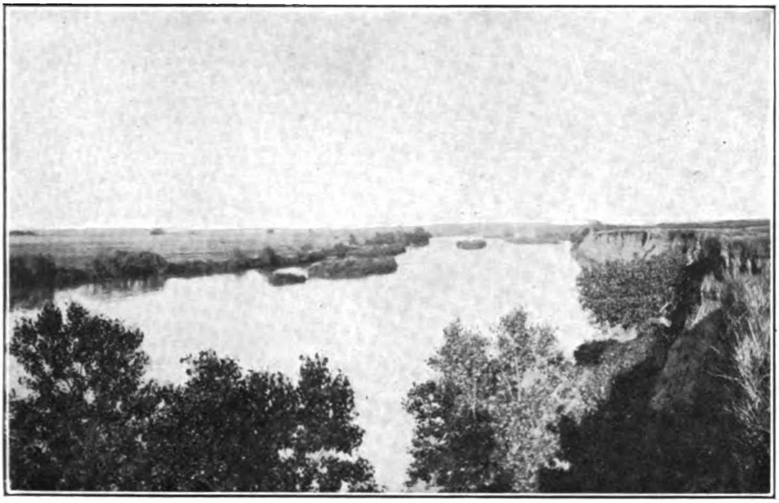
The principal affluents are South Fork, Frenchman River, and Medicine, Sappa, and Prairiedog creeks. In Colorado its valley is mostly in porous Quaternary and Tertiary deposits, but in Nebraska it is excavated in impervious Cretaceous rocks. Throughout its course the river flows over a deposit of alluvium of its own deposition. The depth of the valley bottom below the bordering table-lands and loess plains varies from 200 to about 400 feet.

The stream is mostly shallow and relatively wide and its sandy bed is bordered by low sandy banks, except in places where it cuts into bordering terraces, where the banks are higher and precipitous. The river scours its right bank much more than the left. A typical view of the river is given in Pl. IX, *A*.

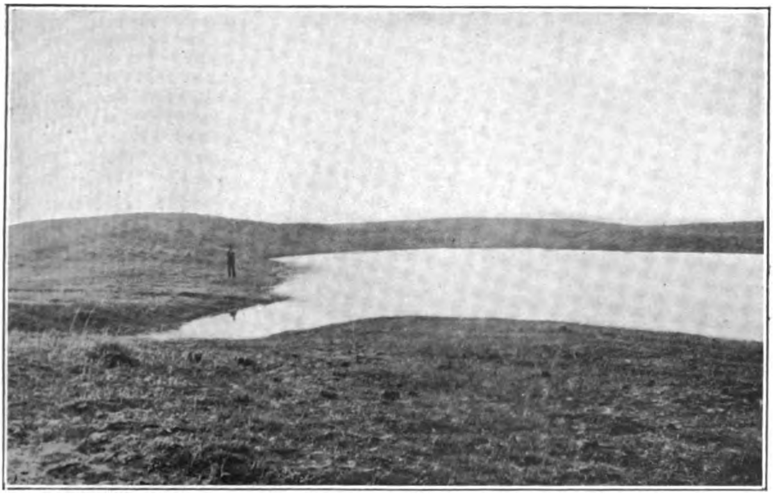
Throughout its course the stream is supplied by spring-fed tributaries. In the western counties, where the rainfall is small and direct run-off is rapid, the river bed often is dry in midsummer immediately above the mouths of Buffalo, Rock, and Frenchman creeks, while the flow from these streams revives the flow in the river below their mouths. This loss of water at the surface is due to evaporation, especially where the water is used for irrigation. Such alternating dry and running portions of the course of the river extend as far east as Superior during periods of drought. Only once in twelve years has the river ceased to flow at Red Cloud and Superior. The river water is useful mainly for stock, irrigation, and power. The following data were compiled by Mr. J. C. Stevens, of the United States Geological Survey:

Estimated monthly discharge of Republican River at Benkelman, Nebr., 1895, 1903, 1904.

Month.	Maximum.	Minimum.	Mean.	Total.
1895.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-feet.*
March (30 days)	162	29	78	4,640
April	95	33	59	3,510
May	281	0	25	1,540
June	830	34	155	9,220
July	656	41	120	7,380
August	102	0	34	2,090
1903.				
May (20-31)	71	47	58	1,380
June	81	43	59	3,510
July	112	19	39	2,400
August	61	26	32	1,970
September	47	19	39	2,320
October	54	43	49	3,010
November (1-20)	64	50	56	2,220
1904.				
March	111	46	89	5,478
April	124	30	65	3,870
May	99	23	54	3,310
June	227	46	91	5,430
July	211	5	40	2,520
August	165	10	29	1,780
September	46	0	15	892
October	195	30	61	3,750
November	87	55	65	3,810



A. REPUBLICAN RIVER SOUTH OF BOSTWICK, NEBR.



B. SAND-HILL LAKE, DUNDY COUNTY, NEBR.

Estimated monthly discharge of South Fork of Republican River at Benkelman, Nebr., for the years 1903–1905.

Month.	Discharge in second-feet.			Total.
	Maximum.	Minimum.	Mean.	
1903.				*Acre-feet.*
May (20–31)	57	36	48	1,140
June	65	7	37	2,200
July	36	7	15	922
August	79	7	25	1,540
September (1–5 and 14–30)	22	7	15	655
October	50	22	39	2,400
November (1–20)	65	50	57	2,260
1904.				
March	102	31	60	3,690
April	66	6	21	1,260
May	255	47	92	5,680
June	397	47	132	7,850
July	115	5	39	2,420
August	89	11	24	1,480
September	47	5	13	774
October	115	31	57	3,540
November	66	47	59	3,580
1905.				
March (17–31)	249	96	159	4,730
April	300	52	141	8,390
May	137	52	100	6,150
June	283	21	68.6	4,080
July	152	5	35.4	2,180
August (1–13)	96	21	47.7	1,280

Estimated monthly discharge of Republican River at Superior, Nebr., 1897–1903.

[Drainage area, 22,347 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1897.						
March	650	385	510	31,360	0.023	0.026
April	2,870	620	1,244	74,020	.056	.062
May	1,130	180	420	25,820	.019	.022
June	[a] 750	180	359	21,400	.016	.018
July	4,310	119	922	56,690	.041	.047
August	1,460	94	259	15,920	.012	.014
September	241	0	71	4,220	.003	.003
1898.						
April	[b] 2,180	490	755	44,980	.03	.03
May	1,870	500	1,053	64,750	.05	.06
June	2,300	560	1,235	73.490	.06	.07
July	1,340	220	479	29,450	.02	.02
August	380	100	195	11,990	.01	.01
September	470	185	289	17,200	.01	.01
October	365	145	264	16,230	.01	.01
November	[c] 470	320	382	22,730	.02	.02
1899.						
March	[d] 956	601	706	43,410	.031	.015
April	842	375	578	34,390	.026	.029
May	1,800	292	511	31,420	.023	.026
June	4,040	141	531	31,600	.021	.023
July	1,380	209	458	28,160	.020	.023
August	868	136	303	18,630	.014	.016
September	102	6	50	2,980	.002	.002
October	101	24	53	3,260	.002	.002
1900.						
April	1,670	565	909	54,090	.04	.04
May	2,940	320	735	45,190	.03	.03
June	674	250	392	23,330	.02	.02
July	349	67	159	9,780	.006	.007
August	1,280	24	149	9,160	.006	.007
September	2,010	8	156	9,280	.006	.007
October	148	26	69	4,240	.003	.003
November	[e] 162	36	87	5,180	.004	.004

[a] June 1–25.
[b] April 20–30.
[c] November 1–19.
[d] March 19–31.
[e] November 1–24.

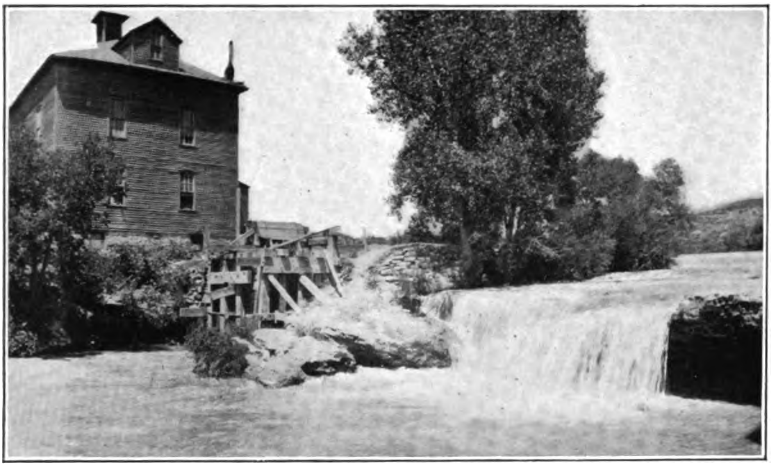
Estimated monthly discharge of Republican River at Superior, Nebr., 1897–1903—Cont'd.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1901.						
April	1,510	637	961	57,180	.043	.048
May	622	146	364	22,380	.016	.018
June	480	117	219	13,030	.010	.011
July	154	5	44	2,620	.002	.002
August	856	5	70	4,300	.003	.003
September	4,990	10	1,246	74,140	.056	.062
October	1,490	285	443	27,240	.020	.020
November	1,030	312	419	24,930	.019	.021
1902.						
March	[a] 920	330	675	29,450	.03	.02
April	740	390	555	33,020	.02	.02
May	2,810	335	1,269	78,020	.06	.07
June	8,240	320	1,372	81,640	.06	.07
July	12,490	970	[b] 3,080	[b] 189,360	[b] .14	[b] .16
August	1,920	330	674	41,440	.03	.03
September	10,880	156	1,175	69,910	.05	.06
October	1,990	520	937	57,610	.04	.05
November	970	460	622	37,010	.03	.03
1903.						
March	[c] 7,750	1,260	2,692	96,110	.120	.080
April	1,260	705	918	54,620	.041	.046
May	14,100	845	4,491	276,140	.201	.232
June	6,460	835	1,921	114,310	.086	.096
July	7,820	465	1,948	119,780	.087	.100
August	8,280	520	1,230	75,630	.055	.063
September	700	270	389	23,150	.017	.019
October	390	245	326	20,040	.015	.017
November	690	130	417	24,810	.019	.021

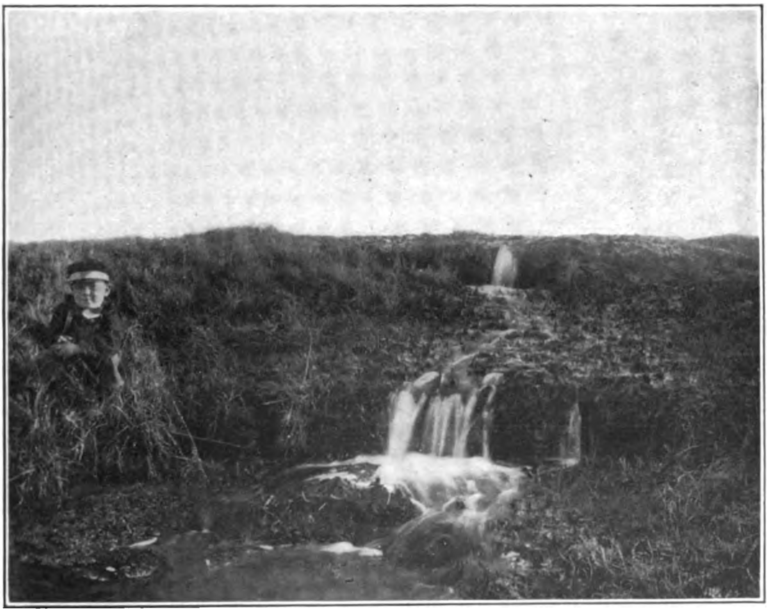
[a] March 9–31. [b] Exclusive of four days' flood discharge. [c] March 14–31.

FRENCHMAN RIVER.

Frenchman River is fed by several tributaries in Chase, Perkins, and Hayes counties and flows southeastward to join the Republican at Culbertson. Only a small part of its drainage basin is within the region to which this report relates. The upper tributary streams are in deep, steep-walled canyons and gather most of their water from springs issuing from the Tertiary. Farther downstream, where the slopes decrease in grade, the valley widens and is cut in Pierre clay. Near its mouth the stream is shallow and from 75 to 100 feet wide. It flows over a sandy bed in which there are small sand bars and islands. At Wauneta, in Chase County, the river falls about 8 feet over a hard ledge of Tertiary rock, as shown in Pl. X, *A*. A flour mill is run by power from this fall.



A. FALLS OF FRENCHMAN RIVER AT WAUNETA, NEBR.



B. SPRING IN DUNDY COUNTY, NEBR.

Estimated monthly discharge of Frenchman River at Palisade, Nebr., for 1895 and 1896.

Month.	Maximum.	Minimum.	Mean.	Total.
1895.	*Second-feet.*	*Second-feet.*	*Second-feet.*	*Acre-feet.*
March	118	98	105	6,460
April	156	107	137	8,150
May	158	111	129	7,930
June	600	50	132	7,850
July	580	54	158	9,720
August	437	64	96	5,900
September	98	68	78	4,640
1896.				
May	200	92	114	7,010
June	800	50	104	6,190
July	145	80	94	5,780
August	92	63	76	4,670
September	89	77	82	4,880
October	89	76	82	5,040

REDWILLOW AND MEDICINE CREEKS.

Redwillow and Medicine creeks are similar to each other in origin and flow, and although they have a long course they carry but a small volume of water. They rise in canyons near Platte River, in Lincoln County, and flow to the Republican through deep narrow valleys in a nearly level upland. Each has sufficient power for the successful operation of flour mills.

BEAVER AND SAPPA CREEKS.

Beaver and Sappa creeks are much alike in flow and drainage area, heading in the vicinity of the Colorado line and receiving the run-off of a considerable portion of northwestern Kansas. They flow northeastward parallel to the Republican, unite in the eastern part of Furnas County, and join the Republican near Orleans. Both creeks flow over a bed of alluvium lying on the Niobrara formation. The volume of water is small, but the flow is constant in the Nebraska part of their courses, where it is augmented by the run-off and by several tributaries fed by small springs. Only one gaging is on record. It was made on Beaver Creek one-fourth of a mile below the mill at Stamford by J. A. Green, July 6, 1904. The surface width below the confluence of the creeks is 21 feet; the area of the cross section of the stream is 33 feet; the mean velocity 95 feet, and the discharge 36 second-feet.

PRAIRIEDOG CREEK.

Prairiedog Creek rises in Kansas, but flows for a few miles through Harlan County, which it enters with volume about as great as that of Sappa Creek. Near its mouth, south of the town of Republican, the creek cuts into the Niobrara chalk, which causes small rapids in its bed. The stream is not now used in Nebraska either for power or irrigation.

LITTLE BLUE RIVER.

Little Blue River is next to the Republican in volume. Its tributaries rise in the loess plains, principally in the vicinity of Hastings, and gather water from the long slopes extending to the brink of the Platte Valley. The general slope of the drainage basin is southeastward, and the river flows into Kansas in the southeastern part of Jefferson County. The drainage area comprises approximately 13,000 square miles, in Webster, Nuckolls, Thayer, and Jefferson counties; in this region the flow is constant, even during periods of dry weather. Much of the water is derived from springs issuing from Quaternary sands and from Dakota sandstone. The river rises considerably during freshets, and during these times has a strong tendency to shift its channel in the sandy bottom lands. During the past year the stream has straightened its course at several places, cutting across some valuable farm lands, notably between Endicott and Steele, south of Alexandria, and near the Chicago, Rock Island and Pacific Railway bridge between Hebron and Gilead. These changes in the channel cause much damage to land, crops, and roadways, and they are much more frequent on this stream than on the Republican.

SPRINGS.

Springs have their source in ground water which issues at the surface under various conditions. The principal horizons at which springs occur in the region are (1) the contact zone between the Tertiary and the underlying Pierre and Niobrara formations, (2) the base of Quaternary materials of western origin where they overlie impervious Cretaceous beds, and (3) the Dakota sandstone, especially when this lies above clay beds.

Many small and a few large springs appear at the first-named horizon, which extends along the entire length of Republican River in Nebraska to its headwaters in Colorado. Most of these springs are located north of the river, the strongest being at or near the heads of tributaries. Among the best examples are those on the Moore ranch northeast of Haigler (Pl. X, *B*), and a spring near Trenton.

In the counties as far west as Hitchcock, and as far east as Franklin, both Tertiary and Quaternary sands yield spring water, but along the tributaries of Little Blue River in northern Thayer and Jefferson counties water comes entirely from the Pleistocene sands. Big Sandy Creek is a good example of a stream which derives its water from these sands.

Spring water from the Dakota sandstones appears to come from two sources. Part of it from distant sources is artesian water escaping along the outcropping area of the formation from eastern Thayer County to the Kansas line. Some of this water flows into the same streams that receive water from the Quaternary sands. The Dakota sandstone outcrops south of Rose Creek, probably derive their spring water from the local rainfall, the water percolating down to clay beds and then outward to the surface.

LAKES.

In the undissected loess plains much of the rainfall is caught and retained in the soil and in numerous temporary ponds during wet weather. Some of these ponds are 8 to 10 feet deep after exceptionally heavy rains, and while a few contain water throughout the year most of them either remain marshy or dry up during the summer months. Such ponds occupy only a small part of the surface in the level uplands, and they are most frequent in counties lying just north of the eastern part of the region. Some of the wet-weather lakes have been drained and the land thus reclaimed for agricultural purposes.

In the sand hills, where the drainage channels are poorly defined, the rainfall soaks into the sands and at the time of heavy rains water fills the basins sometimes to a depth of several feet. Humus and fine silt carried into the basins help to check the downward movement of the water, causing it to accumulate at the surface during rainy weather. There are several examples of such lakes in Dundy County, notably between the heads of Buffalo and Rock creeks (Pl. IX, *B*).

Storage of surface water by means of artificial ponds has been practiced to some extent, especially near heads of spring-fed streams. Examples of this kind are found in Rock and Buffalo creeks of Dundy County. There are lakes also at various localities where the water is held by mill dams.

UNDERGROUND WATERS.

SOURCE OF GROUND WATERS.

The volume of water absorbed by the ground near the surface varies not only with the amount of precipitation but also somewhat with topographic conditions, which promote or retard surface drainage, and especially with the porosity of the soil. Some of the absorbed water is lost by evaporation and some percolates to lower levels. The loess is porous and the vertical structure of the formation is a favorable feature, but the fine texture of the material greatly diminishes its capacity for absorption. The rate of motion of water downward through the various formations varies with the texture and pressure, the motion being more rapid in coarse sands and gravels than in rocks of finer texture. The Cretaceous clays are of such fine grain that they check the downward motion of the ground water, thus often causing it to accumulate in the more porous overlying sands and gravels. The thickness of the latter varies from 0 to 100 feet, and the amount of ground water which they hold is very great. The Tertiary and Quaternary sands and gravels, when completely saturated, contain from 25 to 30 per cent or more of water. Owing to underflow, however, the beds are usually not filled to the top but only up to a subsurface plane, which may be level or sloping, known as the " water table."

Water stored underground in this manner is often the accumulation of many years. The amount is increased and the water table raised by an increase in rainfall, and is lowered correspondingly during long periods of drought. This subsurface storage of water is the main supply for springs and wells and is a source of much of the moisture supplied to growing crops.

QUALITY OF UNDERGROUND WATER.

Underground water contained in the different geologic formations varies much in quality, quantity, and accessibility. Tertiary sands and gravels usually carry an abundance of soft to medium-hard water at moderate depths. The water of the other formations is slightly hard, " alkali " or saline, containing minerals dissolved from the rocks during the slow percolation of the water. Pollution by organic matter is also common, especially in surficial deposits. Most of the Cretaceous formations contain considerable soluble mineral matter, and as a result, their waters often are not of good quality. This is especially the case with the Pierre, Niobrara, Carlile, and Graneros formations, the supply from which is often unfit for domestic purposes. The porous sandstone of the Dakota formation usually yields good water in large supply, but it is hard and often heavily charged with iron. Not a few wells in this formation yield water too saline for drinking and house use. Alkali water is most common in regions where the Pierre shale outcrops or lies close to the surface.

The waters from Tertiary sands have wide distribution and are readily accessible. Often they contain but little mineral matter, although water from the alluvium sometimes contains much alkali, derived from the underlying Pierre shale.

DEPLETION OF SUPPLY.

The water supply near the surface is subject to considerable variation in amount, for there is constant evaporation and a natural drainage to lower levels.

The amount of underground water lost by seepage or springs is considerable. It would be much greater, however, were it not for the usual presence of a loesslike alluvium along the seepage horizon in the main valleys, which checks the rapid flow of water to the surface.

Considerable water near the surface also is lost by evaporation, a factor which increases in importance from east to west. From an open water surface the evaporation averages about twice the precipitation in the western counties of Nebraska. Water stored deep in the soil is not subject to much loss by evaporation. Water drawn from wells, though comparatively inconsiderable in relative amount, is a direct drain on the underground supply.

SHALLOW WELLS.

Water of good quality and in large amounts can be obtained by wells at moderate depths in most of the region treated in this report. The principal sources of supply are the Dakota sandstone, Quaternary sand, gravel, and alluvium, and the Tertiary deposits. Wells are bored, drilled, driven, or dug, and the casings most used are wood, galvanized iron, stone, tile, and gas pipe. In some instances no casing is required.

The shallowest wells are along valleys, and the deepest wells, which vary from 100 to 300 feet in depth, are on the uplands. The local conditions in each county are presented more specifically on later pages in this report.

WEAK AND DRY WELLS.

The volume of water which may be pumped from a well within a given time depends on several factors, the principal one of which is the rate at which water is delivered to the well from a water-bearing formation. This is controlled more by the size of the spaces between the grains of sediment than by the depth to which a well is sunk below the water table, a fact illustrated by a well at N. J. Allen's ranch, 12 miles northeast of Haigler. At first this well ended above the " magnesia " rock and the water was supplied from fine sand and all the water could be pumped out in thirty minutes. When the pump was stopped the water slowly rose again to the level of the water table. Later the well was deepened to reach a bed of coarse gravel, which yielded water in such volume that apparently it was not weakened by three hours pumping with a gasoline engine having an output of over 15,000 gallons. This type of well is duplicated at many other places on the uplands, for the conditions are similar over a wide area. The well on the ranch of Mr. J. McAlee, on the bottom below Benkelman, is one of the best examples of a strong valley well deriving its water from alluvium. This well is 1 foot in diameter and 27 feet deep, and when pumped at the rate of 150 gallons a minute the water level is lowered only a short distance. It then remains stationary during vigorous pumping and as soon as the engine is stopped the water rises to its normal level in a few seconds. The source of supply here is in coarse gravel lying on Pierre shale.

In some wells the water is supplied from fine sands, and, although the volume of water may be large, yet its movement to the well is so slow that the yield is small. One of the best ways to obviate this disadvantage is to increase the size of the well, which gives a larger reservoir in which the water may accumulate.

Weak wells also result when the water table is greatly lowered by dry seasons.

In the case of some weak wells the supply can be increased by sinking to greater depth, providing of course the Cretaceous shales or chalk rock are not entered.

In some districts wells fail to obtain any water, but these are almost invariably in localities where the surface of either the Niobrara or the Pierre formation rises above the water table. A narrow zone presenting these conditions borders each side of the Republican Valley throughout its course in Nebraska and extends for some distance up its tributaries. It is due to the fact that the Republican and its tributaries have eroded their valleys from 30 to over 100 feet in depth in the Cretaceous clays, permitting the ground water in the overlying formations to drain out on the slopes. The width of these zones varies considerably and is greatest where the tributary valleys are long and frequent and there are numerous deep ravines. As soon as the well driller strikes Pierre clay or the Niobrara formation he should discontinue the well and move to a point farther from the breaks at the edge of the valley, if an upland well is desired, or to some point on the valley bottom below. The ideal cross section of a valley shown in fig. 2 will serve further to illustrate the conditions described above. The escape of water is checked by loess and terrace materials on the right side of the section shown in this figure.

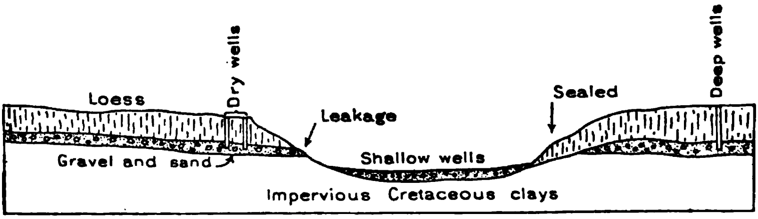


FIG. 2.—Section across a valley in southwestern Nebraska, illustrating the ground-water conditions.

In T. 7, R. 25, northwest of Cambridge, much trouble has been experienced in obtaining water. A well there, 130 feet deep, reached the Niobrara and found no water, while another well 2 miles farther north tapped the water table and an abundance of ground water at

110 feet. In that region as elsewhere the depth to ground water increases while passing from the edge of the dry-well zone to the higher level upland. There are five dry wells on sec. 36, 12 miles south of Trenton. Near Deer Creek, 7 miles northeast of Cambridge, there are seven such wells on 1 acre of the Sullivan farm, each reaching the Niobrara formations at a depth of over 100 feet. After sinking the holes on the Sullivan farm the driller moved 20 rods northward and obtained plenty of water in a well somewhat shallower.

BLOWING WELLS.

Blowing wells occur in most counties in southern Nebraska, the largest number being in Jefferson, Thayer, Dundy, and Hitchcock. They are present in the loess area where the water level is some distance below the top of the underlying gravels, the upper beds of the latter being dry.

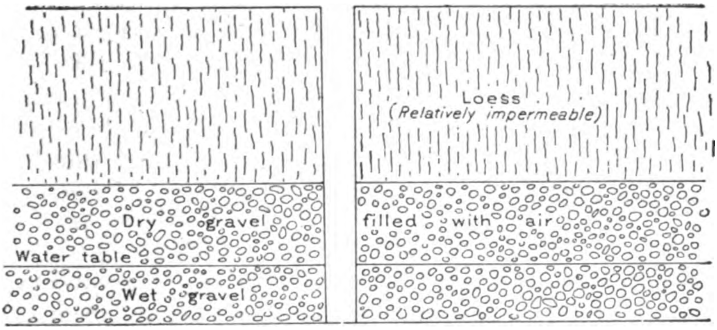


FIG. 3.—Section showing blowing-well conditions.

The cause of the motion of air in these wells appears to be changes in pressure of the atmosphere with which the periods of inhalation and exhalation closely correlate. Fig. 3 shows the conditions under which "blowing wells" occur.

During the time of high barometer or heavier air pressure air moves down the well into the dry gravel, and when the atmospheric pressure diminishes the air comes out of the well. At times of stationary pressure there is no movement. The well, then, is an artificial opening between the loess-covered gravel, with its spaces filled with air, and the surface, where pressure is frequently changing. The loess is so much less pervious to the air than the gravel is that the movement of air through it is very slow, while the well affords a ready channel for upward or downward movement. The velocity of the movement of course varies with the difference in pressure between air in the gravel and that at the surface, with the porosity of the gravel and of the overlying loess bed, and with the depth and diameter of the well. The strongest blowing is usually in wells of small diameter. Changes in the water level also increase or diminish the thickness of the dry gravel; a rise of the water table to top of the gravel would displace the air.

A well at the ranch of C. E. Weeks, 4 miles northeast of Fairbury, is a good example. It is 118 feet deep and a strong blower.

A well at Harbine, owned by George Wells, will blow the hat off of one's head. Numerous other similar examples occur on the uplands north of Alexandria, Stoddard, Hubbell, Indianola, and Benkelman. The blowing appears to bear little or no relation to the available water supply. During the coldest times of winter much trouble is experienced by the freezing of pipes, due to the inhalation of cold air, and in the well of C. E. Weeks, referred to above, the water pipe sometimes has frozen as far down as 100 feet.

Numerous pumps in the upland wells near Arapahoe have to be pulled during the coldest periods of winter on account of bursted pipes. A safety cock is now placed in most pipes about 30 feet below ground, and in very cold weather it is opened to serve as a drain. By this method and by the use of hot water freezing is often prevented. Blowing wells also are natural barometers and thus indicate approaching changes in the weather.

POLLUTION OF SHALLOW WELLS.

As well water is supplied from the surface of the ground by percolation it is subject to dangerous contamination from drainage from outhouses, barnyards, and pigpens. No part of the farm home should be guarded with more care than the well, for polluted waters are frequently the source of disease. Wells should be cleaned frequently, and curbing that has begun to give odor and taste to the water should be replaced. Often decaying casing will render good water unfit for use. The well should be so situated that surface drainage will be away from the well and never toward it.

In case there are two or more water-bearing formations from which a supply of water for domestic use may be obtained, the well should be located so as to secure the more suitable water. The problem is not so much the amount as the quality, when the supply is to be used for drinking purposes. It should be better understood that shallow poorly kept wells are a certain source of disease, and that their proper location and care is essential for the health of all those using the water.

Along the chalk bluffs in the Republican Valley there is a tendency to place the well below the house and lots, usually well on the valley bottoms, where there is plenty of water but increased possibilities of pollution. At many such places wells can not be sunk above the house because of the Niobrara or Pierre formations in the valley slopes, which do not yield good water, but even under this circumstance they can be located out of the line of drainage from the barn and other unclean spots. If placed up-valley from the house, lots, and outhouses the chances of pollution are greatly lessened.

WINDMILL PUMPING.

Water is raised by windmills at many places in the valleys and on the uplands from wells of various depths. The primitive method of lifting water by bucket and windlass is now rarely seen, having been supplanted by windmills, there being usually enough wind to propel these for at least part of the day.

IRRIGATION FROM WELLS.

It has been hoped that the wells of the uplands and valley bottoms of the southwestern counties of Nebraska would yield enough water for the irrigation of large areas, but the supply has been found inadequate at most localities. There is, however, sufficient water for use in gardens for raising fruit, vegetables, and flowers, and, to a limited extent, for certain crops. The best known irrigation plant using well water is on the valley bottom a short distance southeast of Benkelman (see Pl. XI, *A*), at the ranch of Mr. J. McAlee, where a 20-acre garden has been irrigated for two years from a single well 27 feet deep. The water is raised by a gasoline engine pumping 150 gallons a minute into a reservoir covering three-fourths of an acre to a maximum depth of 6 feet. During the year 1903, the income from the garden was $960, after losing much by frost.

ARTESIAN WELLS.

One purpose of this investigation was to ascertain the prospects of securing flowing wells, but the results were not altogether conclusive. The Dakota formation, containing a thick mass of water-bearing sandstones, underlies most of the region described and should be expected to yield artesian flows along at least a part of the Republican Valley. It is overlain by impervious clays and shales in the counties from Thayer westward, and while these beds are not of great thickness apparently, no boring thus far drilled in the Republican Valley has reached the Dakota sandstone. Unsuccessful attempts have been made at or near Arapahoe, Indianola, McCook, and 5 miles east of Haigler. The boring at Arapahoe was discontinued at about 912 feet when the drill must have been very near the Dakota sandstone. A weak flow, which continued for a short time, was found at a depth of about 550 feet. A well at McCook, about 405 feet deep, flowed a few gallons a day. The water in both wells appears to come from the Niobrara formation.

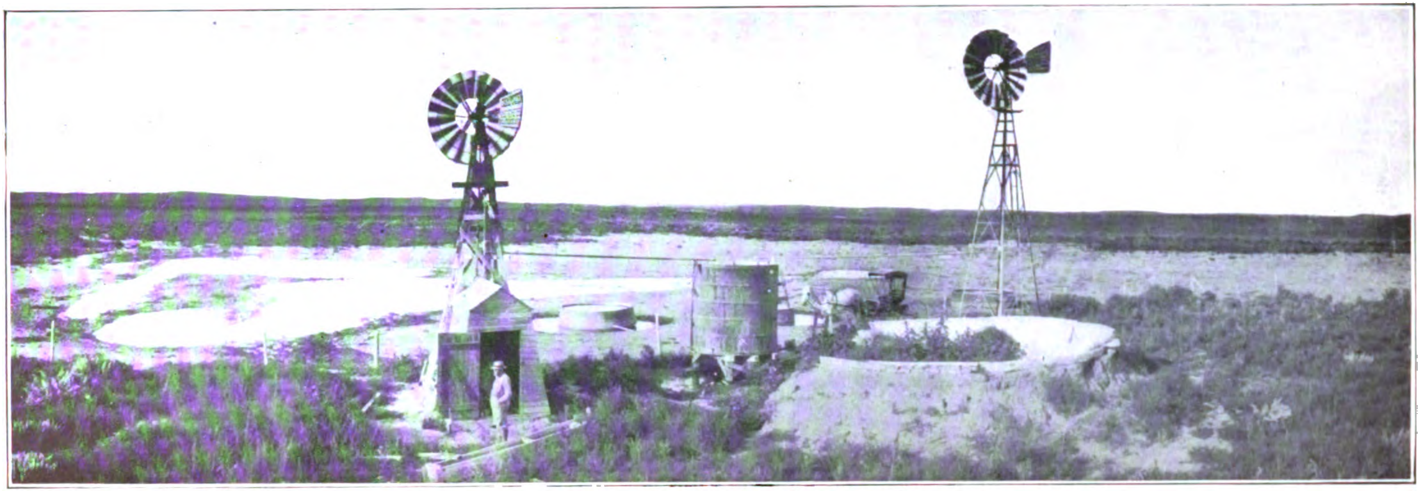
There are several unfavorable conditions for satisfactory flows in southern Nebraska. In the first place the outcrop of the Dakota formation extends across Jefferson County and southwestward across Kansas, and the leakage by springs and seeps is so complete that the artesian pressure is finally all lost. To the west there is a gradual rise of pressure toward the intake zone along the mountains, but the rate is low, perhaps not as much as the general rise at the bottom of the Republican Valley, especially from Furnas County eastward. The margin is small either way, and the true condition can be determined only by a boring in the valley sufficiently deep to penetrate the Dakota formation. A second factor is found in the structure of the Dakota formation: The sandstone or water-bearing beds, where exposed in Jefferson County, appear to be interrupted by clay beds which are usually near the middle of the formation, but which may possibly cut off or displace the sandstones locally. If such a condition exists under the western counties the continuous underground motion of the water might be greatly hampered. In general the beds outcropping appear to show a less favorable structure for an artesian supply under heavy pressure than is found along Missouri River in South Dakota and northeastern Nebraska. Wells reaching the Dakota sandstones in Jefferson and Thayer counties often obtain saline water, which is usually under some pressure, but with one exception, not under enough to lift it to the surface.

The Permian beds have been reached by at least two wells in Jefferson County. In one of them 3 miles south of Fairbury and 336 feet deep, saline water rose 200 feet. Near Steele a weak saline flow was obtained at 195 feet. These examples indicate that there is sufficient pressure in the Permian beds to force water to the level of the bottom lands along the river in the southern part of Jefferson County. The quality, however, is unfavorable for domestic and stock purposes.

A few wells in Tertiary deposits find water under slight pressure. A well of this kind, located on the place of Mr. J. W. Kinsley, 10 miles north and 2 miles east of Benkelman, has the water level so near the surface that it could be piped out.

There is a small area of flowing wells about Alexandria on the valley bottom adjoining Big Sandy Creek. It extends some 4 or 5 miles east and west and about the width of the flood plain north and south. The flow was discovered and developed by Mr. E. N. Averill, who has four or five wells. The first well, which was put down in 1899. did not flow at first, but now there are about twenty flowing wells. They vary from 40 to 60 feet in depth; passing through soil, 2 to 4 feet; sands, with first water, 30 to 35 feet; blue clay, about 5 feet; and peaty clay or old soil to water in coarse alluvial sand or fine gravel. Most of the wells are bored 11 inches in diameter and cased with wood, though in some the casing is galvanized iron. One of the

A. McALEE IRRIGATION PLANT AT BENKELMAN, NEBR.



B. WINDMILLS IN SAND HILLS OF WESTERN NEBRASKA.

Averill wells, only 2 inches in diameter, flows 50 gallons per minute, has a head of 4 feet, and temperature of 49° F. The water is forced by a ram to a 500-gallon tank 600 feet distant and 24 feet above the well, from which it is piped through Mr. Averill's residence.

The other wells flow into a pond used as a source of ice, for boating, and for fish culture. This pond is 250 by 350 feet across and 5 to 6 feet deep. The first well completed at the pond (see Pl. XII, *A*), flowed 110 gallons per minute.

The source of water appears to be in the Dakota sandstone which immediately underlies the alluvial valley filling. The basin, as has been shown, is small and local, and the pressure is sustained by a clay bed which overlies the water-bearing sand.

WATER SUPPLY, BY COUNTIES.

DUNDY COUNTY.

All Dundy County is underlain by the Pierre shale, the surface of which rises 25 or 30 feet above the river at Max and Benkelman and about 100 feet in the vicinity of Buffalo Creek and Haigler. Next above is the Tertiary, which in the northwestern part of the county has been worked over into dune sands and in other sections is overlain by loess. The alluvium along the Republican averages between one-half and three-fourths mile wide, exclusive of the higher terraces.

South of the river the water supply varies considerably as to amount and quality and wells often fail to obtain a sufficient supply, while in the southeast wells ending in the Pierre shale afford bad water. Along the bottom lands water is obtained at depths ranging from 15 to 60 feet, the deeper wells being located on benches. Some of the water varies in quality from hard to alkaline. At Benkelman a good supply of water is reached at depths varying from 20 to 112 feet, the deeper wells being high on the valley slope. The well at Mr. J. M. McAlee's irrigation plant at Benkelman has been described on page 43. An equally strong well, also sunk in the alluvial gravels, affords water for the Burlington and Missouri River Railroad. It is reported to have supplied 50,000 gallons of water in four hours.

Farther up the Republican Valley the best supplies of well water are secured from the alluvium on the north side. At Haigler, located on a bench on the south side, the wells are deeper than usual, being from 45 to 60 feet deep. They afford water of poor quality, owing to the underlying Pierre shale. A town well is used as a public watering place, but the water now used for domestic purposes and drinking is hauled from a shallow well near the river.

In the uplands north of the river the ground-water table varies considerably in depth. In the sand-hill region it is reached by shallow wells varying from 10 to 80 feet in depth, while on the highest part of the divide, between the Frenchman and the Republican, the depth is from 200 to 308 feet, the amount decreasing to the south and the west. In all this part of the county the water table is not easily lowered by the hardest pumping. The water is usually soft or medium hard. At most places it occurs in two horizons in the Tertiary, one above and the other below a fairly definite zone of "magnesia" rock, parts of which are extremely hard and difficult to dig or drill through. Some wells derive their water from the rock. Most of the recent deeper upland wells are tubular, but during the early occupation of the country dug wells were most common. In one dug well three and one-half days were required for penetrating a hard bed 3 feet thick.

Tributaries of the Republican from the north are fed by some of the strongest springs in Nebraska, but while most of the strong, heavy springs are located in the north-side valleys there are also a few on the south. A notably strong spring occurs on the Drummond place, 6 miles northwest of Haigler, from which the water is piped one-fourth mile to the stock yards and house.

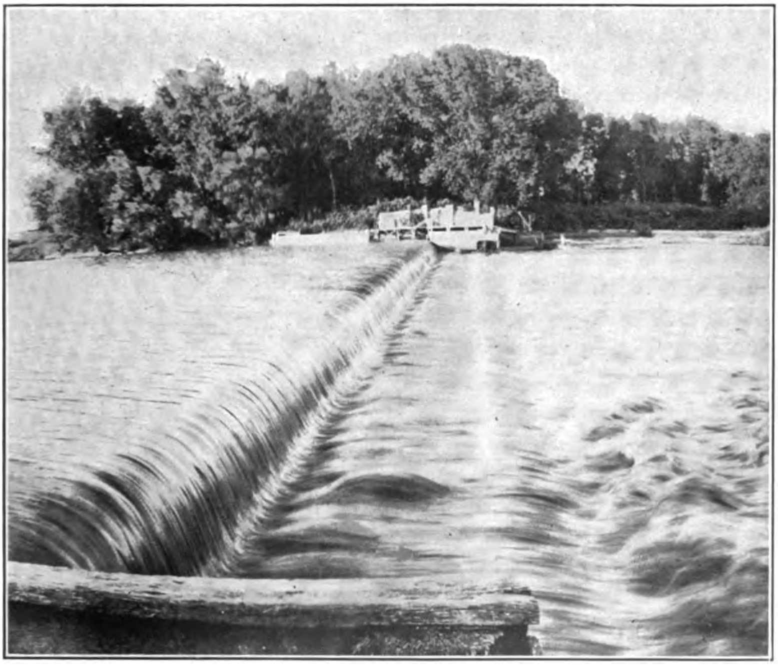
Representative wells of Dundy County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
McAlee, J. M	Benkelman, on bottom	27	24	Sand and gravel to Pierre clay; water in gravel.
Arla Cattle Co	Parks, on Rock Creek bottom	28	12	Soil, sand, and gravel.
Allen, N. J	Sec. 20, T. 1, R. 40, near bottom.	30	10	Dry sand 12 feet; coarse wet sand to water in gravel.
Larned, William	Sec. 33, T. 1, R. 41, near bottom.	40	20	Soil, loam, and sand.
Brady, James	Sec. 25, T. 1, R. 42, on bottom	42	8	Soil, gravel, and Pierre shale.
	Sec. 31, T. 2, R. 36, on bottom	30	10	Soil and sand.
Tockler, A. A	Sec. 14, T. 2, R. 38, on upland	80	....	Soil and sand 27 feet; "magnesia" rock to water.
Allen, N. J	Sec. 19, T. 2, R. 40, sand hills	63	30	Soil, sand, and black loam 27 feet; gravelly sand 2 feet; quicksand 18 feet; "magnesia" rock 7 feet to gravel.
Richards, I. B	Sec. 14, T. 3, R. 36, highland	209	3½	Loess 100 feet; soft sand rock 8 feet; sand 5 feet; clay 20 feet; rock 58 feet; clay, rock, sand, and gravel to water.
Lewis, F. B	Sec. 1, T. 3, R. 37, low slope	48	13	
Larison, F. M	Sec. 8, T. 4, R. 37, highland	225	....	
Johnson, M. M	Sec. 20, T. 4, R. 36, highland	245	15	Soil, loess, and "magnesia" rock.
Nesmith, M. W	Sec. 17, T. 4, R. 36, highland	238	....	Soil, loess, sand, and "magnesia" rock to water.
Ough, William	Sec. 17, T. 4, R. 37, highland	200	14	Black soil 5 feet; clay 140 feet; sand 12 feet; "magnesia" 30 feet; rock 5 feet; gravel 8 feet.
Krausmick, E	Sec. 24, T. 4, R. 37, highland	262	15	Soil, loess, and "magnesia" rock.

HITCHCOCK COUNTY.

The principal streams in Hitchcock County are Republican and Frenchman rivers and Driftwood Creek, the valley slopes of which are formed by Pierre clay, Tertiary deposits, and loess. Frenchman River is a valuable source of irrigation water, while the Republican varies greatly in volume.

A. ARTESIAN WELL AND RESERVOIR AT ALEXANDRIA, NEBR.



B. DAM IN REPUBLICAN RIVER AT SUPERIOR, NEBR.

Springs are numerous, and they supply much water for domestic purposes and stock. Most of them are located north of the Republican and issue at scattered localities from the Pierre-Tertiary contact. The explanation of their irregular distribution is the varying height to which the impervious shales and clays rise above the river, and the presence in places of a covering of either loess or alluvium, which often prevents the surface escape of water. In the vicinity of Trenton the Pierre-Tertiary contact extends along the valley slopes at or near the surface at a level about 20 feet above the bottom land, and springs often appear along it. A few miles east and west the water horizon is more deeply covered on the slopes, and springs cease. About midway between Trenton and Culbertson the Tertiary contact extends down nearly to the level of the river, and the spring horizon is lowered correspondingly. Springs south of the river lie principally on the north branch of the Driftwood, only one of good size being found on the south branch.

Most of the uplands are covered by loess underlain by Tertiary water-bearing sands and gravels with occasional beds of the so-called " magnesia " rock. Impervious Pierre shale underlies all of the county below the Tertiary and prevents water from sinking below the base of the Tertiary deposits.

Bottom lands along the Republican in Hitchcock are broader than in Dundy County. Those of the Frenchman vary from ½ to 1 mile in width. It is stated that the average depth of wells in the bottom lands in the county is from 25 to 35 feet. An abundance of good cool water is usually obtained in coarse alluvial sand or gravel just above the Pierre shale, and while wells often reach this shale, they do not penetrate it. The water table in the alluvial beds rises and falls with the river near the channel, but the influence is local. The quality of the water at places along the outer edge of the flood plain near the Pierre shale slopes is often unsatisfactory. This condition is found at Stratton, where the supply varies from good to bad from wells averaging 30 feet deep. Most wells in Trenton are driven. Several years ago a well was sunk near the depot of the Burlington and Missouri River Railroad in that town to a depth of 300 feet. No accurate record was kept, but doubtless the drill penetrated the Pierre shale and may have extended a short distance into the Niobrara formation.

Wells on the upland in this county resemble those in the eastern part of Dundy County. On the higher lands near the Frenchman they are often deeper, one being 347 feet. It passed through soil, loess, and Tertiary rock, sand, and clay, to water-bearing gravel. The depths on the uplands between the Republican and the Frenchman vary from 100 to over 300 feet, and the first water is always found below thick beds of " magnesia " rock, and usually above a bed of clay. The second water lies in coarse sands and gravel. Blowing wells are not uncommon where there is a bed of dry gravel above the water-bearing horizon. Water in the deep wells on the upland is said to be warmer and softer than that obtained along the Republican bottom. It is claimed that there is a notable difference between the waters of the upland wells and those in Trenton.

The deepest wells on the uplands in the southern part of the county are 220 to 240 feet, and in some of them 85 feet of "magnesia" rock have been encountered above water. On the school section, 12 miles south of Trenton, 5 dry wells were put down, all ending in Pierre shale.

Representative wells of Hitchcock County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Powers, J. H	Sec. 16, T. 1, R. 32, upland	96	12	Soil, 2 feet; loess, 1 foot; silt to within 1 foot of water-bearing sand, and gravel at bottom.
Brumley, M. M	Sec. —, T. 2, R. 35, upland	90	8	No record.
Frey, J. W	Sec. 14, T. 2, R. 33, upland	127	10	Do.
Small, John	Sec. 3, T. 2, R. 33, bottom	13	6	Do.
Miller, C. J	Sec. 5, T. 3, R. 33, upland	196	12	Black loam, 50 feet; soft rock. 80 feet; dry sand, 2 feet; sand 64 feet; water in sand above rock.
Morgan, T. D	Sec. 34, T. 3, R. 33, upland	100	7	Black soil, 4 feet; loess. 85 feet; sand and gravel, 16 feet
Powers, C. R	Sec. 35, T. 3, R. 33, upland	108	....	Black soil, 3 feet; loess. 70 feet; sand, 30 feet; gravel. 5 feet.
Williams, J. M	Sec. 12, T. 4, R. 32, lowland	42	....	Soil, clay, and sand to water.

REDWILLOW COUNTY.

The streams of most importance in Redwillow County are Republican River and Redwillow, Driftwood, and Beaver creeks. They flow in rather wide bottom lands from 200 to 400 feet below the highest uplands. The underlying formations are the same as those found in the next county west, except that near the eastern border the Pierre thins out and the Niobrara gradually rises so that it attains an elevation of 100 feet above the river near Cambridge.

Wells on the bottom land range from 20 to 50 feet in depth. At McCook large amounts of water are drawn from this source for railroad and city use, six large wells having been dug on the first bottom to a depth of 26 feet to the top of the Pierre shale. At Indianola the water lies from 12 to 20 feet below the surface, but most wells are driven to gravel at a depth of 45 or 50 feet. A few wells near the valley slopes in the northern part of the town reach ocherous Niobrara beds and yield a poorer quality of water. On the broad bottom lands near the mouth of Redwillow Creek water lies within a few feet of the surface, and at the Redwillow store a well is driven 20 feet in the soil and sand. In the uplands south of Indianola the water is in Tertiary rock and gravel, and is reached by wells from 100 to 260 feet in depth, most of them being 140 to 160 feet deep.

It is reported that there are good water supplies in the uplands south of Indianola in the region where the formations dip westward. Farther southeast, in the area of ocher and flint, dry wells are common. In the highlands north of Indianola wells range from 150 to 300 feet in depth, and northwest of Cambridge from 100 to 125 feet.

The water table in the uplands in this county lies approximately level, a feature due to the configuration of the surface of the underlying impervious beds, which rise 100 feet above the river near Cambridge and only a few feet above at McCook.

Springs, though found at a number of places in the county, are not as large nor as numerous as in adjoining counties.

A deep boring at McCook has been reported as having penetrated 405 feet[a] of the Pierre shale, but for most of the distance it was in Niobrara formation, of which it did not reach the bottom. The flow is weak and unfit for use.

Representative wells of Redwillow County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Schippe, G. P.	Lebanon, 7 miles E. of, lowland.	48	6	Bench and clay.
Bennett, Donald	Lebanon, 5 miles E. of, lowland.	40	....	Bench and clay; loess.
Brandt, Fred	Wilsonville, 6 miles W. of, upland.	160	3	Loess, rock, clay, sand; small supply.
Brockman, Frank	Wilsonville, 5 miles W. of, upland.	120	3	Loess, clay.
McMurrin, D. H.	Sec. 20, T. 1, R. 30, upland	170	7	Loess and magnesia rock.
Anderson, Andrew	Sec. 11, T. 1, R. 30, upland	27	5	Loess and rock.
Caldwell, L. C.	Sec. 10, T. 1, R. 30, upland	155	4	Sand, loess, magnesia rock.
Benjamine, W. A.	Sec. 23, T. 1, R. 30, upland	229	8	Soil, loess, rock, sand, clay, gravel.
Moore, Frank	Sec. 24, T. 2, R. 26, upland	150	....	Soil, soft sandstone, 24 feet; coarse gravel, 4 feet; small supply.
Reper, Geo. P.	Sec. 3, T. 2, R. 29, on slope	70	....	Soil, gravel, sand.
Rodgers, E. E.	T. 2, R. 29, 3 miles SW. of McCook.	75	10	Loess, sand.
Lincoln Land Co.	Sec. 29, T. 3, R. 29, McCook	405	407	Sand, and Pierre and Niobrara formations; small flow.
Boyce, N.	Boxelder post-office, 2 miles E. of, upland.	162	10	Soil, 2 feet; loess, 60 feet; Tertiary rock, 80 feet; Tertiary rock and sand, 18 feet; Pierre 2 feet.
Sharp, William	T. 4, R. 30, 7 miles NW. of McCook, upland.	240	4	Loess, rock, gravel.

---

[a] Another deep boring in progress in 1905, with a depth of over 700 feet, was not deep enough to reach the base of the Graneros formation. Some sandstone, penetrated at a depth of about 700 feet, appears to belong to a bed which usually occurs near the top of the Carlile formation.—N. H. D.

FURNAS COUNTY.

The principal streams in Furnas County are Republican River and Medicine, Beaver, and Sappa creeks. Only a small portion of the course of Medicine Creek lies in the county.

Springs are found in several localities, but are not an important source of supply. Those used most are south of the river between Arapahoe and Edison, northeast of Beaver, and about midway between Cambridge and Holbrook. Seepage springs are common along Sappa Creek near the Nebraska-Kansas line and in the small creeks near Arapahoe.

Well water obtained on bottom lands along the valleys is usually good, but at places it contains alkali, especially in shallow wells on the first bottom. Most wells at Cambridge are on the bottom lands and on an average are driven 35 feet to second water; the first water, somewhat alkaline, is reached at 10 to 15 feet. In Holbrook, Arapahoe, Edison, and Oxford similar conditions prevail, except that in Arapahoe the second water is found only in a few localities and dry wells are more frequent. These dry wells are due to the Pierre shale rising so high as to cut off the ground water.

At certain points, as at the park well, the alluvium deepens locally. The park well is 8 feet in diameter and 44 feet deep; below its bottom four 3-inch sand points extend to a total depth of 48 feet.

In Wilsonville, Hendley, and Beaver the water supply is derived from alluvial sands and gravel lying immediately above Cretaceous shale. At Wilsonville first-water wells are about 20 feet deep. The second water lies in sand under clay about 18 feet below the first water, and is reached by wells 35 to 40 feet in depth. At Hendley second water is obtained in wells 40 feet deep. Conditions along the Beaver and Sappa bottoms are similar to those at Wilsonville and Hendley, but there are dry wells at places.

Wells on the uplands between the Republican and Beaver vary in depth from 100 to 260 feet, with an average of about 150 feet. They pass through much Tertiary rock. On the ranch of William Dickerson, between Beaver and Arapahoe, 100 feet of rock were encountered. In the well on the ranch of William Rone, 6 miles south and 2 miles east of Arapahoe, the water rises considerably. In a well 7 miles north of Beaver the water rises nearly to the surface, and might be drained out, giving a continuous flow.

On the slopes near the valley bottoms much trouble has been experienced with dry wells, but this feature is less frequent north of the Republican than south. The best known dry-well areas are located east of Hendley, northeast of Beaver, and on the slope south of the Republican, the last named extending nearly across the county. The wells in most cases end in the Pierre shale, at an elevation of from 20 to 40 feet above the level of the river. In the southwestern part of the county they end in the Niobrara at still higher levels.

On the upland north of the river the water table is from 100 to 140 feet below ground, varying with the distance from the valley. The second water lies in gravel about 40 feet below the first, the two being separated by rock. Some wells, extending only to first water, dry up during times of drought.

Tubular wells are losing favor in Furnas County. The points clog up by the deposition of mineral matter within a few years, and as a result they have to be pulled and cleaned in order to obtain a necessary supply of water.

Prof. A. d'Allemand, of Arapahoe, furnished the writer with a log of the 912-foot boring drilled in 1894 at that town, but it is difficult to make out a very accurate section from the log. It was discontinued on account of a disconnected drill which was not removed from the hole. The drilling ended in the Graneros shale, apparently near the Dakota.

Representative wells of Furnas County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Young, L. W	Sec. 3, T. 1, R. 25	85	....	Sand and sand rock alternating.
Anderson, R. A	Sec. 21, T. 1, R. 25, upland	190	....	No record.
Landgrun, John	Sec. 9, T. 1, R. 24, upland	180	....	Loess, sand, Tertiary rock.
Burns, G. C	Sec. 25, T. 2, R. 25, bottom	38	12	Terrace-alluvium and gravel
Johnston, Sam	Sec. 31, T. 2. R. 25, bottom	40	8	Do.
McComb, J. P	Sec. 31, T. 2, R. 25, bottom	40	10	Do.
Hanug, L. P	Sec. 22, T. 2, R. 24, upland	109	10	Loess, clay, sand; small supply.
Do	Sec. 23, T. 2, R. 24, upland	85	10	Do.
Pierce, C. H	Sec. 27, T. 2, R. 24	40	15	Loess, clay, Niobrara.
Snodderly, Henry	Sec. 30, T. 2, R. 24	30	3	Tertiary rock to gravel and water.
Larson, Victor	Four miles NW. of Hendley	196	5	Loess, sand, Tertiary rock and shale; small supply.
Powell Bros	1½ miles E. of Hendley	200	None.	Loess, shale.
Daniels, M	Sec. 25, T. 3, R. 21, upland	186	6	Loess, sand.
Zehe, Peter	Sec. 24, T. 4, R. 23	35	7	No record.
D'Allemand, A	Arapahoe	36	8	Loess-like clay, clay, gravel.
Vanralin, I. J	Sec. 18, T. 4, R. 23	35	....	Soil, sand.
Daniels, S. W	Sec. 19, T. 4, R. 20, lowland	78	60	Soil, clay, sand, gravel.
Trammel, J. W	Oxford	65	18	Soil, loess, sand, and water, rock, gravel.

HARLAN COUNTY.

Pierre shale underlies most of Harlan County, but the Niobrara chalk rock is exposed along lower levels of the principal valleys.

A sufficient supply of good water is obtained in most parts of the county, yet dry wells are not uncommon in or near towns along the Republican and at places on the uplands near Prairiedog Creek. Wells on the first bottom of the Republican range from 12 to 30 feet in depth. Those on the terrace in the lower part of Alma vary from 45 to 50 feet; in the north part of that town they are about 70 or 80 feet, while at a higher level on the slope the depths are somewhat less, a condition hardly to be expected. The water table lies at about the same depth under the benches and first bottom at Alma, Orleans, and Republican, and the wells at each place are similar, except that more difficulty has been experienced with dry wells at Orleans than at the other towns named. At Stamford it has been found difficult to obtain good water. The town is located on a high bench in which the Pierre shale rises above the water table.

On the uplands between the Republican and the Prairiedog valleys, the water is contained in Tertiary sands and gravels beneath a bed of rock; the wells range from 100 to 150 feet in depth, the deepest one, 170 feet, being an exception.

At a few miles distant from the river on the high land north, water is usually obtained from Tertiary gravels lying beneath rock. Farther away from the river it is reached in sands lying above the rock. The deepest wells are in the vicinity of Ragan, one being 260 feet.

Wells in the northeastern part of the county, where the shallow lakes occur, vary from 140 to about 200 feet in depth.

Important springs are found along the Prairiedog, northeast of Alma, and at several other localities.

Representative wells of Harlan County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Moore, W. R	Sec. 4, T. 1, R. 19, upland	70	6	Sand-lime rock and clay 20 feet; then rock and sand to water.
Gillispie, D. O	Sec. 3, T. 1, R. 17, on slope	54	....	Soil, sand, clay, sand.
Haskins, M. H	Sec. 15, T. 1, R. 17, bottom	27	....	Soil, clay, sand.
Cook, J. M	Sec. 15, T. 2, R. 20	71	....	No rock.
Smith, James	Sec. 15, T. 2, R. 17, upland	100	5	No record.
Klein, C. F	Sec. 4, T. 2, R. 20, upland	122	8	Do.
Popert, M	Sec. 3, T. 2, R. 20, bottom	40	....	Soil, clay.
Do	Sec. 4, T. 2, R. 20, upland	117	....	No record.
Giles, E. W	Sec. 7, T. 3, R. 20, bottom	70	46	Loess and sand; stopped on rock.
Peck, George	Sec. 19, T. 1, R. 17, upland	90	10	Loess 50 feet; sand 40 feet.
Hutchinson, M. L	Sec. 35, T. 4, R. 20	50	....	Soil, clay, sand, gravel.
Uebel, G. W	Sec. 20, T. 4, R. 20, upland	215	70	Soil, loess, Tertiary rock, sand and gravel to Pierre shale.
Pettygrove, N. A	Sec. 17, T. 4, R. 20, upland	140	20	Soil, loess, sand, gravel.
Bayley, Mrs. D	Sec. 21, T. 4, R. 20, upland	228	83	Soil, loess and Tertiary rock, sand, and gravel on Pierre shale.

FRANKLIN COUNTY.

The underlying impervious beds in Franklin County are the Niobrara chalk rock, which underlies the entire area, and the Pierre shale, which is limited to the western part. The first-named formation rises east of Naponee, carrying the water table high above the river.

The water-bearing beds are the same in this county as in Harlan, but a larger amount of well water is derived from the upland sands and gravels. The locality in which it is most difficult to secure an adequate supply of good water is south of the river, where the wells are usually dry or contain water of poor quality. Their depths average about 100 feet near the State line.

On the lowest bottom lands the water is at a depth of 10 to 20 feet. At Naponee plenty of water is obtained from wells 30 to 40 feet deep. About Bloomington and Riverton there are many unsuccessful wells. A well at the foot of the slope at Bloomington is 46 feet deep, ending in gravel. Another, three-fourths mile north, on the slope is 60 feet deep, supplying good water. At Franklin water is obtained in coarse sand lying above the Niobrara chalk rock.

In the uplands north of the river the water table varies from 100 to about 200 feet in depth, the amount increasing with the altitude. At Moline the average depth to water is about 160 feet, and in the vicinity of Upland it is about 150 feet. In a well at the ranch of James Grant, 2 miles south of Macon, accounted one of the best on the first ridge, the water level is 142 feet below ground. In the vicinity of Campbell the depth to the water table ranges from 150 to 190 feet, and wells vary in depth from 170 to about 200 feet, being shallower along the depressions.

This county has many small springs which feed the creeks north of the river. A good example is the W. E. Ewing spring, three-fourths mile northeast of Franklin. It is used for dairy, house, and stock purposes, and eventually may be piped to Franklin for town use. The fall from the spring to the main part of the town is between 60 and 70 feet.

Representative wells of Franklin County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Miller, W. A	Sec. 11, T. 1, R. 15	20	3	Soil, sand, and gravel to Niobrara chalk.
Hoffhenhe, George	Sec. 2, T. 2, R. 14, upland	130	5 or 6	No record.
Davis, Will	Sec. 11, T. 2, R. 14, upland	132	6	Do.
McGinley, H	Sec. 13, T. 2, R. 14, upland	135	6	Do.
Baker, D. W	Sec. 2, T. 2, R. 14, upland	154	5	Do.
Bauerle, G	Sec. 21, T. 2, R. 16, upland	120	15	Sandy loam and clay; sand at bottom.
James, J. H	Sec. 33, T. 3, R. 13, lowland	36	20	Coarse gravel.
Postmaster (Macon, Nebr.).	Sec. 27, T. 3, R. 15	170	....	Soil, 125 feet; sand, 50 feet.
Byerly, Levy	Sec. 29, T. 3, R. 15	185	....	Clay. 120 feet; sand. 65 feet.
Zulauf, Chas	Sec. 20, T. 3, R. 17, highland	230	....	Black soil and sand.
Dunn, John	Sec. 20, T. 3, R. 16, highland	220	15	No record.
Amman, Paul	Sec. 17, T. 3, R. 16, highland	231	15	Do.
Hansen, J. Martin	Sec. 28, T. 4, R. 14	170	15	Black soil, clay, sand, and gravel.
Lorain, H. B	Sec. 20, T. 4, R. 14, highland	151	12	Sand and clay.
Hansen, Nelson	Sec. 16, T. 4, R. 14	187	....	Clay and sand to water-bearing gravel.

WEBSTER COUNTY.

The underground water conditions in Webster County resemble those described as existing in the eastern part of Franklin County, but the wells average somewhat shallower. Most wells south of the river are in the bottom lands of small ravines, where the chalk rock affords a limited supply of water of inferior quality.

In the uplands north of the river water is obtained from sands and gravel lying between the loess and the chalk rock. It is soft to medium hard, and of good quality. The depths vary from 60 to 100 feet, the deepest wells being in the northwestern part of the county. About Blue Hill and Rosemont the depth to water averages less than 100 feet.

Taken as a whole, the county is supplied with an abundance of good water. Dry wells are found south of the river and at a few places near it on the north. At the ranch of John Griffith, 2 miles west of Red Cloud, a well was driven 225 feet, passing through soil, sand, and the Niobrara chalk rock to the Carlile shale, but it yielded no water. A well in the northern part of Red Cloud extends through loess, sands, and the Niobrara formation to the Carlile shale. The depth is 265 feet, and the water unfit for use.

Inavale, Red Cloud, Amboy, and Guide Rock derive their water supply from alluvial sands and gravel at depths ranging from 20 to 50 feet.

Springs feed most small creeks north of the river. One of the strongest south of the river is about 5 miles from the bridge at Red Cloud.

Representative wells of Webster County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Wild, George	Sec. 32, T. 1, R. 12, ravine	36	10	No record.
Noble, N. S	Sec. 30, T. 1, R. 12, ravine	30	6	Soil, clay, sand.
Sutton, Oliver	Sec. 21, T. 1, R. 12, ravine	30	10	Do.
Dickerson, F. A	Sec. 5, T. 1, R. 9, slope	60	10	Soil, clay, sand, gravel.
Crabill, William	Sec. 7, T. 2, R. 11, slope	88	10	Loess, gravel, sand.
Bondren, Pierre	Sec. 10, T. 3, R. 12, upland	190	6	Soil, 3 feet; loess, sand.
Bean, Emory	Sec. 22, T. 3, R. 12, upland	140	5	Soil, 3 feet; loess, 90 feet; coarse sand, quicksand, pebbles, gravel.
Guerens, Louis	Sec. 5, T. 3, R. 12, upland	180	4	Soil, loess, gravel, sand, small pieces of rock.
Erickson, Mary	Sec. 20, T. 3, R. 11, upland	130	4	Loess, gravel with occasional pieces of rock, and sand.
Snee, Mary	Sec. 35, T. 4, R. 12, upland	160	6	No record.
Hall, Mrs. H. W	Sec. 14, T. 4, R. 11, upland	95	12	Soil, loess, sand, blue clay, sand.
Mattock, J. A	Sec. 3, T. 4, R. 11, upland	100	25	Soil, loess, broken pieces of magnesia, blue clay, sand.
Turner, Mrs. S. F	Sec. 2, T. 4, R. 11, upland	150	30	Loess, sand, blue clay, gravel, blue clay, sand.
James, J. A	Sec. 12, T. 4, R. 10, slope	82	8	Loess to sand and water.
Buschow, F. C	Sec. 10, T. 4, R. 10, slope	76	5	Loess to sand.
Blue Hill	Sec. 9, T. 4, R. 10	200	70	Loess, sand, and gravel.
Buschow, A	Sec. 4, T. 4, R. 10, upland	160	12	Do.
Choats, C	Sec. 17, T. 4, R. 9, upland	85	18	Loess, sand.
Nelson, Peter	Sec. 16, T. 4, R. 9	58	27	Loess.
Buzzard, S. H	Sec. 8, T. 4, R. 9	50	30	Do.

NUCKOLLS COUNTY.

In the uplands of Nuckolls County well water is obtained from sand, often quite fine, lying on the Niobrara formation and Carlile shale at depths ranging from about 60 to 110 feet. In places near valleys where the bed rock is exposed or only thinly covered by sand and soil considerable difficulty has been experienced in obtaining water in sufficient amounts and of a suitable quality. Wells south of the river are much like those similarly located in Webster County. At Nelson certain chalk ridges and dry sand basins have been the cause of unsuccessful wells, while in other locations, in some cases not far away, good wells have been secured.

Towns on benches along the Republican derive a suitable water supply from alluvial sands and gravels.

There are several strong springs in this county, both north and south of the river. The most notable is about 8 miles northwest of Superior. It supplies water for 500 to 1,500 head of cattle.

Representative wells of Nuckolls County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Henderson, C. H	Sec. 23, T. 1, R. 8	35	....	No record.
Reid, Thomas	Sec. 24, T. 1, R. 7	40	11	Soil, loess.
Howsick, E. W	Sec. 23, T. 1, R. 7	51	1	Loess, 30 feet; black clay, 10 feet; sand with water at 46 feet.
Spahn, Geo. S	Sec. 14, T. 1, R. 7	30	5	Loess, shale.
Spahn, Geo. S	Sec. 4, T. 1, R. 7	70	17	Loess, sand, chalk rock.
Henderson, A. J	Sec. 22, T. 1, R. 6	30	3	No record.
Whiting, Mabel	Sec. 26, T. 1, R. 6	48	3	Water in.
Churchill, C. E	Sec. 21, T. 1, R. 5	104	8	Soil, loess, sand.
Kruse, John	Sec. 23, T. 2, R. 8	75	8	Sand and gravel.
Coleman, James	Sec. 27, T. 2, R. 8	40	15	Do.
Yohe, D. M	Sec. 22, T. 2, R. 8	36	5	Sand to water.
Middletown, Wm	Sec. 15, T. 2, R. 8	65	20	Loess, sand, Niobrara chalk.
Stien, C. N	Sec. 14, T. 2, R. 8	72	9	Loess, sand, gravel.
Elledge, Chas	Sec. 13, T. 2, R. 8	72	4	Loess, sand.
Bishop, C. A	Sec. 9, T. 2, R. 8	75	4	No record.
Shaw, William	Sec. 3, T. 2, R. 8	70	4	Some rock.
Baker, W. A	Nelson	90	20	Dark loam, fine sand, clayey to bottom.
Kimmerer, Ira	Sec. 24, T. 2, R. 6	48	....	Loess, sand.
Ruskin	Sec. 15, T. 2, R. 5	120	10	No record; town pump.
Smith, J. C	Sec. 26, T. 3, R. 8	40	20	Black loam, loess, chalk rock.
Beachey heirs	Sec. 34, T. 3, R. 8	70	3	Soil, loess, sand, rock, gravel.
Brockman, M	Sec. 11, T. 3, R. 8	90	....	No record.
Nesbit, J. B	Sec. 14, T. 3, R. 7	28	8	Do.
Wehrman, F. A	Sec. 17, T. 3, R. 7	80	15	Loam, loess, sand, shale.
Montgomery, D. W	Sec. 8, T. 3, R. 5	35	6	Soil, sand.
King, William	Sec. 30, T. 4, R. 8	90	12	Loess, sand, gravel.
Shell, J. F	Sec. 8, T. 4, R. 8	50	9	No record.

THAYER COUNTY.

The water supply of the upland wells of Thayer County comes from sands and gravels lying on the Carlile and Greenhorn formations, the depth ranging from 70 to 150 feet. At a few places the sands and gravels are dry, as at Byron, where much trouble has been experienced in securing good water for the town. This condition probably is due to the fact that the Carlile shale rises and displaces the water-bearing beds. Fortunately the Dakota sandstone lies only about 300 feet below the surface at Byron, and its water is of good quality in that part of the county. Wells recently sunk to this source afford an abundance of water, and under pressure sufficient to raise it more than 50 feet.

The Dakota formation underlies all the western part of the county at a depth of from 300 to 350 feet, and appears to contain less salt than farther east. Along the Little Blue Valley and at places near Rose Creek the water obtained from wells in this formation is somewhat salty, and although in some cases it is not too much so for use, in others it is decidedly objectionable.

The Carlile and Graneros shales outcropping along the Little Blue River and Rose Creek valleys contain but small amounts of bad water, unfit for domestic purposes. The Greenhorn limestone affords water of fair quality to a few wells.

Alluvial sands and gravels are the source of most water supplied to towns located on bottom lands. At Hebron wells averaging from 30 to 40 feet deep extend through alluvium to limestone. The small artesian basin at Alexandria has been described on page 44.

Wells at Hubbell vary in depth from 30 to 40 feet, and their supply diminishes somewhat in dry weather.

Representative wells of Thayer County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Webber, Fred	Sec. 36, T. 1, R. 4	315	100	Loess, sand, 50 feet; shale, 160 feet; limestone, 9 feet; shale to 315 feet.
Gaston, Nelson	Sec. 31, T. 1, R. 3	88	8	Loess, 20 feet; sand, 68 feet.
Forsdick, Stephen	Sec. 35, T. 1, R. 3	150		No record.
Baldwin, D. J	Sec. 9, T. 1, R. 2	125	5 or 6	Loess, 80 feet; sand and gravel, 45 feet.
Burdick, A	Sec. 31, T. 1, R. 1	725		No record.
Aufderheide, J. H	Sec. 13, T. 2, R. 4	98		Water in coarse sand 3 feet thick.
Werner, Phil	Sec. 11, T. 2, R. 4	106		No record.
Thiernan, H. B	Sec. 5, T. 2, R. 4	105		Do.
Cornell, E. M	Sec. 6, T. 2, R. 2	20	5	Do.
Dufur, William	Sec. 1, T. 2, R. 2 W	27	10	Soil, sand, and gravel: at base of limestone bluff.
Wheeler, Jennie E	Sec. 4, T. 2, R. 1 W	71	36	Soil, shale, slate, flint.
Houser, Joseph	Sec. 2, T. 2, R. 1 W	100	18	Soil and sand, 10 feet; lime rock, 13 feet; blue shale with occasional hard beds, 75 feet; sandstone, 2 feet; poor supply.
Thiernan, W	Sec. 25, T. 3, R. 4	36		Soil and loess, 20 feet; sand, 4 feet; coarse sand and gravel 12 feet.
Meyer, John	Sec. 21, T. 3, R. 4	120		Loess, sand.
Elting, Charles	Sec. 18, T. 3, R. 3	147		No record.
Scharatt, H. J	Sec. 8, T. 3, R. 3	112		Do.
Upton, R. B	Sec. 4, T. 3, R. 3	92		Do.
Schainost, Fred	Sec. 36, T. 3, R. 1 W	55	22	Sand, shale.
Hergott, Joseph	Sec. 25, T. 3, R. 1 W	32	2	Soil, 2 feet; clay, 8 feet; limestone and beds of clay, 22 feet.
Knape, O	Sec. 36, T. 3, R. 1 W	173	40	Soil, limestone, shale, sandstone.

Representative wells of Thayer County, Nebr.—Continued.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Hergott, Joseph	Sec. 35, T. 3, R. 1 W	150	18	Soil and clay, 5 feet; limestone with clay beds, 25 feet; shale to water in sandstone.
Bulin, A.	Sec. 12, T. 3, R. 1 W	192	16	Soil and loess, 70 feet; limestone and clay to water in sandstone.
Dill, M. C.	Sec. 7, T. 3, R. 2	70	7	Soil, 2 feet; loess, 61 feet; coarse sand and gravel, 7 feet.
Mahoffy, S. A	Sec. 14, T. 4, R. 4	80	....	Loess, 30 feet; sand, 50 feet.
Wright, G. N	Sec. 36, T. 4, R. 4	94	....	No record.
Bice, A. W	Sec. 24, T. 4, R. 3	84	8	Do.
Bushnell, Scott	Sec. 22, T. 4, R. 2	90	....	Loess, 40 feet; sand, 50 feet.
Thompson, George	Sec. 11, T. 4, R. 2	85	....	Soil and gumbo, 2 feet; loess, 18 feet; sand and clay, 65 feet.

JEFFERSON COUNTY.

The occurrence of underground water in Jefferson County is very irregular. In localities where the Graneros and Carlile shales are not overlain by water-bearing sand or gravel, the only alternative is to drill or bore into the Dakota sandstone, which supplies water in abundance, indeed, but varying in quality with the locality. In localities where the Graneros shale extends high up the valley slopes, good wells are rare, unless they extend through the shale into the Dakota sandstone. Some of the wells in this sandstone yield good water, but in many of them it is saline, examples of the latter being found at Gladstone and at a number of points between Powell and Steele.

In much of the county a thick deposit of Quaternary sands and gravels beneath the loess affords an abundance of water at depths varying from 70 to 160 feet. These sands and gravels are extensively developed in the uplands east of Fairbury, about Jansen. and north of the Big Sandy.

At Powell the first water in the alluvium lies within a few feet of the surface. At Fairbury, on the bottom lands, where Pleistocene and alluvial sands blend so that it is difficult to distinguish between them, they carry a large supply of water, reached by wells varying from 30 to over 100 feet in depth, the deeper wells being on the valley slope. At Endicott and Steele the supply comes from the Dakota sandstone and alluvium. About Jansen wells usually derive their water from Quaternary sands, but the deepest one extends a short distance into Dakota sandstone.

Numerous springs, some of considerable size, occur among the deep ravines along Rose Creek and other tributaries of Little Blue River. A hotel in Steele is supplied by spring water. A general seepage into Big Sandy and Little Blue River from the Dakota formation and Pleistocene sands occurs in the northwestern part of the county.

Representative wells of Jefferson County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Wimer, Eli	Sec. 31, T 1, R. 1 E	15	7	Soil, clay, limestone, clay.
Lobaugh, J. M	Sec. 32, T 1, R. 1 E			Rock, clay, soapstone.
Simmons, James	Sec. 28, T. 1, R. 1 E	30	20	No record.
Shepherd. Alex	Sec. 16, T. 1, R. 3	68	9	Soil, sand, gravel.
Boggs, J. O	Sec. 3, T. 1, R. 3	81	45	Soil, 4 feet; loess, 10 feet; Dakota clay, 66 feet; sand, 1 foot.
Connell, John	Sec. 10, T. 2, R. 1 E	281		Soil and clay, 35 feet; sand. 65 feet; slate, soapstone, and a little coal.
Carmony, F. A	Sec. 14, T. 2, R. 2 W	90	6	Loess, 2 feet; sand, 16 feet; clay, 3 feet; sand, 19 feet.
Bodarge, William	Sec. 21, T. 2, R. 2	135	30	Soil, 20 feet; lime rock, 30 feet; chale, 60 feet; soapstone, 20 feet; on sandstone with water.
Wells, Ed	Sec. —, T. 2, R. 3	310	175	Loess and soil, 60 feet; sand and gravel, 70 feet; clay, 180 feet; gravel and sand; water.
Spicer, J. R	Sec. 10, T. 2, R. 4	40	18	Loess and sand.
Landkamer, Geo	Sec. 21, T. 3, R. 1	18	7	Hard pan.
Weise, John	Sec. 4, T. 2, R. 4	125	20	Loess, except 5 feet; black clay and 3 feet glacial sand.
Akin, A. M	Sec. 32, T. 3, R. 1	100	16	Loam and limestone, 20 feet; slate. 64 feet; sand and sandstone, 16 feet.
Schroeder, J. H	Sec. 30, T. 3 N., R. 1 E	150	50	Soil, 15 feet; slate, 35 feet; limestone; water in quicksand.
Moles, D. P	Sec. 26, T. 3, R. 2	110	40	No record.
Pickens, Wes	Sec. 35, T. 3, R. 2	148	70	Do.
Janert, William	Sec. 35, T. 3, R. 2	227	70	Do.
In town (Jansen, Nebr.).	Sec. 34, T. 3, R. 3	160		Soil, 4 feet; loess, 100 feet; glacial sand, 56 feet.
Wrighley, Jas	Sec. 10, T. 3, R. 4	115	20	Quicksand.
Public well (Harbine, Nebr.).	Sec. 28, T. 3, R. 4	122	4	Loam, except 3 feet of sand at bottom.
Woodman, Art	Sec. 30, T. 4 N., R. 1 E	62	4	Loess, 2 feet; sand, 14 feet; clay, 8 feet; sand.
Frost, Eph. (owner, Newell, H. J.).	Sec. 27, T. 4 N., R. 1 E		9	No record.
Hellwig, Frank	Sec. 26, T. 4 N., R. 1 E	96		Do.
Glenn, Mary	Sec. 23, T. 4, R. 1	60	30	Loam and sand, 40 feet; slate, 2 feet; sand, 13 feet; lime rock, 1 foot; sand, 4 feet.
Wolfe, Cyrus	Sec. 32, T. 4, R. 4	130	6	Soil, 8 feet; loess, 80 feet; glacial drift, 42 feet.

WATER POWER.

GENERAL STATEMENT.

Only a brief statement as to the location and maintenance of water-power sites can be given in this report. The water-power prospects in the Republican Valley region are more important than is generally supposed, the plants now in operation employing only a portion of the total power available. The power is now used principally by flour and grist mills and to some extent for electric-light plants. Climatic conditions are an important factor in the industry, for the winters are so open as to permit the use of power during the coldest months. In the western counties there are many sites with limited power along small spring-fed streams, but farther east, where the run-off is greater and streams are supplied liberally from underground sources, greater and more lasting powers are found.

As yet the demand for power is not great. Much grain is now shipped outside the region which might be milled in the valley were it not for the lower shipping rates for wheat than for flour. As a result of this condition the product of most mills is only for local use and but little power is required to grind it. With increasing population, however, and the usual high price of fuel there will be an increasing need for water power.

The power sites are in the basins of Republican and Little Blue rivers and the more favorable locations are on the strongest tributaries. On these the fall or grade per mile is somewhat greater than on the rivers and short dams impound enough water for the mill pond at small expense. Along the rivers dams need to be longer, and consequently are more expensive to construct and to maintain. Republican River usually dries up in the western counties during a part of the summer, a condition which prevents successful development of water power there. Farther east the constant flow affords ample supply, but occasional high waters are apt to cut a new channel to one side of the dam or to do it much damage. This is especially true where the dam lies on sandy alluvium.

POWER SITES IN THE REPUBLICAN VALLEY.

Several years ago water powers were in operation on Republican River at Oxford, Alma, Franklin, and Red Cloud. Periods of drought and high water brought about their disuse, except at Red Cloud, where the mill was burned. Three powers are now operated along the Republican, near Arapahoe, at Orleans, and at Superior. The dam at Superior is shown in Pl. XII, *B*.

Powers might be obtained at reasonable cost at several places on tributaries of the Republican. The flow of Buffalo Creek in Dundy County varies but little during the year and continues all winter. The stream gages about 10 second-feet with a fall of about 15 feet per mile. Power for use about the house has been employed by Mr. N. J. Allen, who diverts a part of the flow in his irrigation ditch over a small wheel which can be connected to either a churn, washing machine, or grindstone. Aside from this the power of Buffalo Creek is not utilized, and at present there is little demand for it. Rock Creek is nearly as strong as Buffalo Creek and could be made to yield small powers.

Several small powers are available on Frenchman River. Those at Wauneta and Palisade, both outside the area treated in this report, are of most value, the former utilizing a natural fall of 7 feet and an artificial fall of over 1 foot. Redwillow Creek has a dam and mill.

A successful power, located on Medicine Creek, at Cambridge, runs a mill all the year and practically night and day. A site now not in use is on Big Muddy Creek, northwest of Arapahoe. There are 3 dams in the Sappa-Beaver Creek basin—at Stamford, Beaver, and Wilsonville. A mill formerly operated in the Sappa was moved to Superior, where it is now running. Small spring-fed streams afford sufficient water for small powers at Naponee, Bloomington, and Franklin.

POWER SITES IN THE LITTLE BLUE RIVER BASIN.

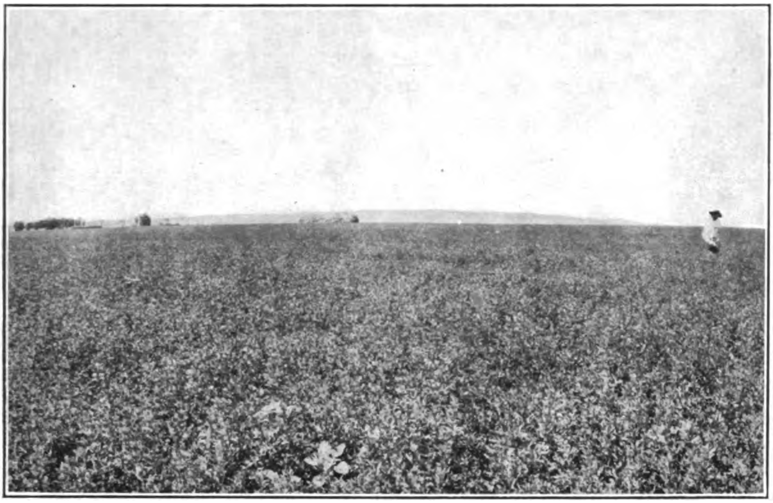
There are 8 dams now in the Little Blue basin, while another, formerly located near the abandoned town of Meridian, was destroyed by high water.

Most dams in the basin have been damaged by high waters and on that account their maintenance is expensive. The most trouble has been experienced at Hebron and Fairbury. At the former place the river is held in position at heavy expense, because the stream has a strong tendency to cut across the bottom just east of the dam and mill. At Fairbury most of the old dam has been replaced recently by a concrete dam, which it is thought will better cope with high waters. If a dam on the Little Blue is made too high the flow of the stream is diverted over the low banks and the sandy flood plain at times of high water, threatening not only the abutment of the dam but other property as well. Dam sites now in use in this basin are at or near Steele, Fairbury, Alexandria, Hebron, Deweese, Oak, and Blue Bluffs.

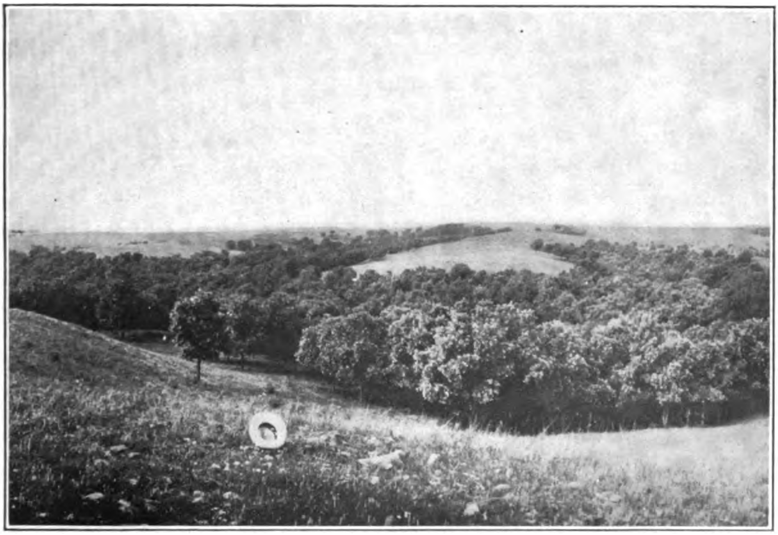
IRRIGATION.

The principal irrigation now in operation in the Republican Valley region is on the valleys and bench lands, though in some cases the ditches extend out on the lower adjacent valley slopes. The extent of irrigable land is moderately large, but the supply of water is not adequate for reclamation of the entire area. In the eastern and central counties the average rainfall is sufficient for the growth of crops without irrigation, except in an occasional season. At a number of places in the Republican Valley region ditches have been constructed for use during drought, but have been allowed to get out of order during rainy seasons. Furthermore, the principal supplies are at the headwaters of streams, and loss of water by evaporation and seepage during transmission into the broader valleys is great.

It has been found that irrigation along the main valley of the Republican in the western counties is practicable only near the headwaters and below the mouths of some of the strong tributary streams. The best results in that region are obtained between Haigler, Nebr., and Laird, Colo. (see Pl. XIII, *A*), about Benkelman, and along the Frenchman, near Culbertson.



A. IRRIGATED ALFALFA FIELD NORTHWEST OF HAIGLER, NEBR.



B. BUR-OAK GROVE NEAR ENDICOTT, NEBR.

According to the State engineer about 35,000 acres are under irrigation in the region described in this report. The total length of ditches is about 130 miles, of which apparently less than one-half was operated in 1904. The number of acres irrigated by counties decreases from west to east. The counties including most of the area are Dundy, 17,415 acres; Hitchcock, 13,070; Redwillow, 3,935. In 1904 the area was much less.

AGRICULTURAL RESOURCES.

GENERAL STATEMENT.

The utilization of the part of the Great Plains where there is but little rainfall has been a subject of much study. Different methods have been employed from time to time, but they have failed to bring the results which their promoters had hoped to attain. At times stock raising has been thought to be the only industry adapted to the sand hills and dry uplands, while again it has been thought that grain crops might be grown over a large portion of the area. The successes and failures in the unfavored sections have been varied. Settlement has increased and decreased in periods corresponding with the amount of rainfall.

The early attempts at forestation by planting "tree claims" gave poor results, probably because the planting was done crudely and groves were not properly cared for. Very few of the thousands of groves thus started have survived, but a few successful ones show that, if carried on with greater care and with species suited to the climate, good results may be attained.

The introduction of drought-resisting and early-maturing crops is thought by some to be an important factor in reclamation. The crops thus far grown are the forage crops and varieties of oats and wheat.

Dry-farming methods adapted to the rainfall are being promoted at a number of places. The aim is to hold as much of the water in the soil as is possible by proper tillage. The main enemy to soil storage of water is evaporation, and by maintaining a mulch the loss in that manner is reduced to a minimum. To what extent this method, commonly called the Campbell system, will aid in reclamation is not fully proved. It is promoted by the Chicago, Burlington and Quincy Railroad, apparently with good results, and promises to become valuable.

SOILS.

Agriculture is by far the most important resource of the region, but its results are greatly affected by the local variations in climate. ground water, and soils. The rainfall and ground-water conditions have been described above, but the many different kinds of soils have not been differentiated. In general, the distribution of the different types corresponds with that of the geologic formations, but minor variations exist, often of considerable importance in plant growth. There are in the region three fairly distinct agricultural provinces—the loess table-lands, the alluvial bottom lands, and the sand hills.

The loess plains of the wide table-lands between the valleys occupy the greater part of the area treated in this report. Where the streams have cut through the loess, the various underlying formations appear with soils of different kinds extending in narrow belts along the valley slopes. Glacial soils, which occur mostly in Jefferson County, are clayey or sandy, with an admixture of pebbles and bowlders. Soils on or below outcrops of Dakota sandstone are sandy, but in places are clayey or ocherous. Extensive alluvial soils occur along the rivers and their tributaries. They contain a high per cent of silt or sand and usually a small proportion of clay. Soils formed from the Cretaceous shales and chalk rock extend along some of the valley slopes not covered by loess or alluvium, and are usually of bad quality for agriculture.

In the sand-hill region loose sandy soil of the dunes consists mainly of quartz sand with but little clay, while in the basins and dry valleys there is an admixture of some humus and considerable clay.

The table-land soil is sandy, and may grade into sand hills on one side and into the so-called plains marl or western loess on the other. The talus slopes below ledges of Tertiary rock are mostly sandy or gravelly.

CROPS.

NATIVE GRASSES AND THEIR UTILIZATION.

The region contains a large number of grasses, the distribution of which is controlled by topographic and hydrographic conditions. The highest and heaviest growth is found on bottom lands and eastward over the valley slopes. The drier uplands are quite thickly matted with "short grass." In the sand-hill region the grass covering mostly is thin, except in the dry basins and valleys. In this region there is often much sagebrush and other herbaceous plants, having but little grazing value. In all the counties the meadow grasses are cut for hay, with a total product estimated at 100,000 tons per year.

Three species of blue-stem grasses are of frequent occurrence: *Andropogan furcatus* is abundant on the bottom lands eastward; *Andropogan scoparius* (bunch grass) is widely distributed, extending over bottom lands, onto ridges, and throughout the sand hills; *Andropogan halli* is found on sand dunes and ridges.

Under the name buffalo grass a number of species are usually included. One of these, *Bulbulis dactyloides*, is widely spread over the dry uplands, and extends as patches in dry basins and valleys in the sand hills. It is very nutritious, and when not too much leached by fall rains serves as one of the best winter foods. The grammas are generally known as buffalo grass, with which they correspond somewhat in distribution and values for grazing. One of them, *Bouteloua oligostachya*, is perhaps the most important dry upland grass. A larger species is more often cut for hay.

The uplands are occupied nearly exclusively at places by wheat grasses, which are not so desirable as the buffalo and grammas. *Stipa conata* is a common species.

CULTIVATED FORAGE CROPS.

Among the cultivated forage crops alfalfa is first in importance. It is most successfully and extensively grown throughout the region on low bench lands, where it has become an important resource. Three or four crops are cut each year, and are used extensively as swine pasture and for hay. Some of the largest fields are near Indianola, Beaver, and Republican. In the counties farthest west irrigation is employed where water is accessible; a typical irrigated field is shown in Pl. XIII, *A*. On the uplands about two cuttings are harvested each year. In the sand hills the crop is now grown at a few places where ground water rises close to the surface.

Timothy and clover are not very extensively grown. The principal forage crops raised during drought times and on the driest lands are sorghum, cane, millet, and hungarian. These require more labor in cultivation than alfalfa, and hence are less popular crops.

The following table, showing the acreage of cultivated forage crops, is compiled from the Nebraska Labor Bureau Report for 1903:

Area of cultivated forage crops.

[Acres.]

County.	Alfalfa.	Millet and hungarian.	Sorghum and cane.
Dundy	618	2,021	5,403
Hitchcock	533	402	10,188
Redwillow	6,956	3,617	8,416
Furnas	10,350	2,540	10,785
Harlan	11,683	1,959	2,262
Franklin	5,882	1,229	2,433
Webster	10,168	2,217	4,396
Nuckolls	8,178	2,544	2,525
Thayer	4,366	1,451	2,271
Jefferson	2,979	3,706	2,405
Total	61,742	21,686	51,084

GRAIN CROPS.

The principal grains cultivated are corn, wheat, oats, and rye. Barley is raised to some extent west of Franklin County. Winter wheat is much more common than spring wheat, especially in the eastern part of the region. The accompanying table, which is based on the labor bureau report, shows the number of bushels of the principal cereals produced in each county in 1903:

Quantity of cereals produced in 1903.

[Bushels.]

County.	Corn.	Wheat.	Oats.	Rye.
Dundy	806,067	40,970	6,559	13,95[illegible]
Hitchcock	668,640	446,855	5,778	172,60[illegible]
Redwillow	1,561,681	1,555,870	24,412	459,25[illegible]
Furnas	1,986,544	1,690.314	76,434	323,125
Harlan	1,966,456	1.300,600	195,397	256,4[illegible]
Franklin	1,961,008	1,066,530	401,131	[illegible]
Webster	2,272,956	1,032,475	452,231	54,72[illegible]
Nuckolls	2.977,652	923,450	485,619	72,4[illegible]4
Thayer	3,212,131	1.018.094	1.025,303	58,119
Jefferson	2,748,461	727,240	4.073,478	16,350
Total	20,161,596	9,802,488	6,746,342	1,475,96[illegible]

FRUIT RAISING.

Numerous wild fruits grow along ravines and in canyons. Cultivated fruits—such as peaches, plums, and cherries—are marketed from a number of large orchards. The W. T. Collins orchards, located on bench lands 1 mile west of Beaver, contain 1,300 peach trees, which were heavily loaded in 1904.

On the place of James Drummond, 6 miles northwest of Haigler and three-fourths mile from the Colorado line, is a successful orchard and vineyard under irrigation. When visited, cherry trees had averaged between 3 and 4 bushels of fruit each, and the apple trees were in promising condition. Mr. N. J. Allen has raised fine peaches and plums by irrigation on a sand-hill point 4 miles east of Haigler. These are but types of a large number of orchards that might be named.

SUGAR BEETS.

Beets are successfully grown under irrigation on the bench lands of the western counties, but the best crops are raised in the Frenchman Valley above Culbertson and at a number of points along the Republican. The following table shows the acreage of beets by counties and the extent of the crop for 1904:

Acreage planted in beets, 1904, in southern Nebraska.

County.	Acres.	County.	Acres.
Dundy	92	Webster	32
Hitchcock	686	Nuckolls	1
Redwillow	690	Thayer	4
Furnas	96		
Harlan	32	Total	1,671
Franklin	38		

STOCK RAISING AND DAIRYING.

Stock raising and dairying are closely related to the grass growth, forage, and grain crops already described. The largest stock ranches are located in the thin and short grass regions where most of the land is cheap, and, owing to its subhumid condition, is better adapted to grazing than to other agricultural purposes. The grasses cure on the sod during the time of diminished rainfall in the late summer and fall months and afford pasturage all winter except at times of deepest snowfall. Thousands of cattle and horses "rustle" during the winter without other food. Some winters this lack of care for stock has resulted in heavy losses, especially in former years when most cattle were not provided for; during heavy snowstorms large numbers died more from hunger than from cold. Of recent years winter feed usually is provided for stock during times of exceptionally severe weather and the percentage of loss is greatly diminished.

The western part of the region to which this report relates lies in that part of the Great Plains which is generally known as the "cattle country," yet the number of animals per square mile in the western counties is less than it is farther east where more corn is grown. The day of the open range has passed; now large areas are fenced, in the grazing counties, and controlled by ranchmen.

In the counties farthest east stock are pastured on the roughest land during the grazing months and fed on rough feed in winter. Swine are raised cheaply and in large numbers where alfalfa is most extensively grown.

Dairying has become one of the important industries throughout the region and is successful during both drought and humid years. The cream is shipped from numerous stations to large creameries.

The accompanying table shows the number and distribution of the principal farm animals for 1904:

Number and distribution of farm animals for 1904.

County.	Cattle.	Hogs.	Horses and mules.
Dundy	15,677	5,002	2,708
Hitchcock	13,995	4,254	3,549
Redwillow	17,663	16,566	4,501
Furnas	33,238	29,688	11,307
Harlan	26,402	21,888	8,546
Franklin	24,926	25,876	7,732
Webster	33,690	34,690	10,089
Nuckolls	22,000	26,939	6,865
Thayer	29,202	26,586	11,487
Jefferson	26,054	27,218	8,303
Total	242,947	218,707	75,087

TIMBER.

Early settlers and prairie fires destroyed much of the natural tree growth, which appears to have been more prevalent at the time of the country's first occupation than it is now. However, the traveler while passing along the open valleys is apt to underestimate the amount of timber growing in the region as, for the most part, it is confined to ravines and the rough lands adjacent to the larger valleys.

Cottonwoods are found both in groves and isolated on all valley bottoms. Along the Frenchman Valley and in the canyons of northeastern Dundy County there are cottonwood trees 2 to 3 feet in diameter, and one located 7 miles northwest of Fairbury is over 6 feet in diameter. Willows, represented by one or more species, are found in all valleys of any considerable size.

Bur oaks follow up and cover the sandy slopes in Jefferson County, and occur westward along the Little Blue and in the lower course of the Republican Valley (see Pl. XIII, *B*). Elms are found in largest numbers on the bottom lands in Jefferson, Thayer, and Nuckolls counties, but extend westward on the alluvium to Dundy County. Parts of Sappa Valley were formerly covered with large elms. Walnut trees of large size grow in the valley bottoms as far west as Red Cloud. A tree nearly 3 feet in diameter is reported south of Naponee.

Ash and boxelders are scattered among other species in the valley portions of the region. Straggling cedars remain on the bluffs of Webster, Franklin, and Nuckolls counties, and a small pine is reported as having been found in a ravine south of Bloomington. The tree growth is utilized for firewood, posts, and lumber.

INDEX.

A.

Page.

- Acknowledgments to those aiding 7
- Aftonian drift, occurrence of 22
- Agricultural resources, description of 61–66
- Air pressure, changes in, blowing wells due to 41–42
- Alexandria, artesian well and reservoir near, view of 46
  - dam near 60
  - wells near 44–45
- Alfalfa, cultivation of 63
  - view of 60
- Allen, N. J., irrigation by 64
  - water power used by 59
  - well of 39
- Alluvium, agriculture on 62
  - occurrence and character of 24–25
  - sand in 29
- Alma, Niobrara rock used at 27
  - water power at 59
  - wells in 51–52
- Amboy, wells at 54
- Analyses. *See name of substance analyzed.*
- Andropogan furcatus, occurrence of 62
  - halli, occurrence of 62
  - scoparius, occurrence of 62
- Anticlines, occurrence of 11
  - gas and oil as related to 26
- Arapahoe, boring at 43
  - sand and gravel near 29
  - water power at and near 59, 60
  - wells near 50
    - freezing of 42
- Arikaree formation, correlative of 19
- Artesian wells. *See* Wells, artesian.
- Ash, volcanic, analysis of 30
  - character and uses of 30
- Atwood Company, quarry of 27
- Averill, E. N., wells of 44

B.

- Baculites compressus, occurrence of 19
- Beaver, fruit raising near 64
  - rainfall at 10
  - sand and gravel near 29
  - water power at 60
  - wells near 50
- Beaver Creek, description of 35
  - flow of 35
  - water power on 60
- Beets, sugar, cultivation of 65

Page.

- Benkelman, irrigation near 43, 60
  - irrigation near, view of 44
  - Republican River at, flow of 32–34
  - wells near 39, 44, 45, 46
  - wind erosion near, view of 24
- Benton group, occurrence and character of. 13–17
  - section of 13
- Big Muddy Creek, water power on 60
- Big Sandy Creek, source of 36
- Birdsall, G. A., fossils collected by 16
- Bloomington, water power at 60
  - wells near 53
- Blowing wells, description of 41–42
- Blue Bluffs, dam near 60
- Blue Hill, wells near 54
- Blue Hill beds, occurrence and character of. 16
- Bostwick, sand near 29
  - view near 32
- Bouteloua oligostachya, occurrence of 63
- Bowlders, occurrence of 22
  - view of 22
- Brick yards, location of 28
- Brown (A.) quarry, operation of 27
- Buffalo Creek, water power on 59
- Buffalo grass, occurrence of 62
- Building stone, rocks furnishing 26–28
- Bulbulis dactyloides, occurrence of 62–63
- Bunch grass, occurrence of 62
- Bur oaks, growth of 66
  - view of 60
- Byron, wells at 55

C.

- Cambridge, Niobrara quarry near, view of. 26
  - sand and gravel near 29
  - water power at 59–60
  - wells near 40–41, 50
- Campbell, wells at and near 53
- Carboniferous rocks, occurrence and character of 10, 11–12
  - oil and gas in 26
- Carlile shale, occurrence and character of... 16–17
  - water of, quality of 38
- Carmody, C. A., fossil collected by 16
- Cattle, number and distribution of 65
- Cement, materials for, and manufacture of. 28
- Cereals, cultivation of 65
- Chemical analyses. *See name of substance analyzed.*
- Clay, character and distribution of 28

Page.
Climate, description of.................... 9-10
Coal, occurrence and character of.......... 25-26
Collins (W. T.) orchards, production of.... 64
Condra, G. E., work of.................... 7
Creeks and rivers, descriptions of.......... 31-36
Cretaceous rocks, occurrence and character of........................ 10,12-19
  water in, quality of.................... 38
Crops, character of......................... 62-64
Culbertson, irrigation near................. 60
  rainfall at............................. 10
  sugar beets near........................ 64

D.

Dairying, practice of...................... 65
Dakota formation, artesian water in.... 26,43-45
  building stone from.................... 26-27
  clay in.............................. 28
  coal in.............................. 25
  ocher in............................. 30
  occurrence and character of............ 12-13
  sand and gravel in..................... 29
  section of............................ 13
  springs from.......................... 36-37
  view of.............................. 14
  water in......................... 26,39,43-45
    quality of......................... 38,44
D'Allemand, A., log of Arapahoe well furnished by...................... 51
Dams, location of........................ 60
  view of.............................. 46
Darton, N. H., on Benton group........... 13
  work of............................ 7,11,26
Deweese, dam near........................ 60
Dickerson, William, ranch of, well on...... 50
Drainage, description of.................. 8-9
Drift, glacial, occurrence and character of.. 20-22
Drummond place, fruit raising on.......... 64
  well on.............................. 46
Dry farming, attempts at.................. 61
Dundy County, crops in.................. 63,64
  geology in.................... 19,24,25,26,45
  irrigation in......................... 61
  spring in, view of.................... 34
  stock raising in...................... 65
  water resources of.................... 45-46
  wells in.............................. 46

E.

Economic geology, description of.......... 25-31
  See also particular minerals.
Edison, volcanic ash at................... 30
  wells near............................ 50
Elephant bones, occurrence of............. 22,24
Endicott, bowlders near, view of.......... 22
  clay near............................. 28
  Dakota sandstone near, view of........ 14
  timber near, view of.................. 60
  wells near............................ 57
Evaporation, water loss by................ 39
Ewing, W. E., spring of................... 53

F.

Fairbury, building stone near............. 27
  clay near............................. 28

Page.
Fairbury, dam near....................... 60
  quartzite near, view of 22
  rainfall at........................... 10
  sand and gravel at.................... 29
  section near.......................... 14
  wells near.......................... 44.57
Fairbury Junction, sand and gravel near... 29
Faults, occurrence of..................... 11
  view of.............................. 14
Fencepost limestone, building stone near... 27
  occurrence and character of............ 15
Flagstone member, occurrence and character of.......................... 15
Forage crops, cultivation of.............. 63
Formations, occurrence and character of... 10-25
Fort Hays beds, correlative of............ 17
Fossils, occurrence and character of... 13-16.18.19
Franklin, rainfall at..................... 10
  section at........................... 30
  water power at...................... 59.60
  view near............................ 30
  wells at and near..................... 53
Franklin County, crops in............... 63.64
  geology in.......................... 19.52
  ocher in............................. 30
  stock raising in..................... 65
  water resources of................... 52-53
Frenchman River, description of......... 34.46
  discharge data of..................... 35
  falls on............................. 34
    view of............................ 34
  irrigation along 61
  water power on........................ 36
Fruit, cultivation of..................... 64
Furnas County, forage crops in.......... 63.64
  geology in....................... 11.19.26
  stock raising in...................... 65
  water resources of.................... 50-51

G.

Gas, natural, occurrence of............... 26
Gay, J. C., volcanic ash mined by 30
Geography, description of 8-9
Geology, description of................... 10-25
  See also Economic geology.
Gilead, building stone near............... 27
Glaciers, topography shaped by............ 8.22
Gladstone, building stone near 27
  wells at............................. 57
Grain crops, cultivation of............... 63-64
Graneros shale, coal in................... 25
  occurrence and character of............ 14
  sections of......................... 13.14
  water of, quality of 38
Grant, James, ranch of, well on........... 53
Grasses, cultivation of................... 62-63
Gravel, occurrence and description of...... 28-29
Great Plains, utilization of.............. 61
Green, J. A., flow measurement by......... 35
Greenhorn limestone, building stone from.. 27
  occurrence and character of............ 14-16
  section near.......................... 13
Griffith, John, ranch of, well on......... 54
Guide Rock, wells near.................... 54

H. Page.

- Haigler, fruit raising near 64
  - irrigated field near, view of 60
  - rainfall at 10
  - sand hills near, view of 26
  - springs near 36
  - wells near 39, 45, 46
- Harbine, flowing well at 42
- Harlan County, crops in 63, 64
  - geology of 51
  - stock raising in 65
  - volcanic ash in 30
  - water resources of 51–52
- Hebron, dam near 60
  - rainfall at 10
  - sand and gravel near 29
  - wells at 56
- Helvey, sand and gravel near 29
- Hendley, wells near 50
- Hiltner, R. S., analysis by 30
- Hitchcock County, crops in 63, 64
  - geology in 24, 26, 46–47
  - irrigation in 61
  - stock raising in 65
  - water resources of 46–48
- Hogs, number and distribution of 65
- Holbrook, wells at 50
- Horses and mules, number and distribution of 65
- Hubbell, building stone from 27
  - wells at 56

I.

- Inavale, wells at 54
- Indianola, ocher mined at 30–31
  - wells at 49
- Inoceramus labiatus, occurrence of 13–16, 18
- Inoceramus member, occurrence and character of 15
- Irrigation, employment of 43, 60–61

J.

- Jansen, wells near 57
- Jefferson County, building stone in 27
  - coal in 25
  - crops in 63, 64
  - geology in 11, 13, 14, 16, 21, 22, 57
  - stock raising in 65
  - water resources of 57–58

K.

- Kansan drift, occurrence of 22
- Kesterson, building stone near 27
  - sand and gravel near 29
- Kinsley, J. W., ranch of, well on 44

L.

- Lakes, occurrence and character of 37
- Lime, manufacture of 27
- Lincoln marble, occurrence and character of 15
- Little Blue River, character of 8–9
  - description of 36
  - power sites on 59, 60
  - valley of, geologic map of 10
- Loess, occurrence and character of 23
- Loess plains, agriculture on 62
  - character of 8

Page.

- Lookout Mountain, sandstone at 27
  - section at 20
  - view of 20

M.

- McAlee, J., ranch of, irrigation on 43
  - ranch of, irrigation on, view of 44
    - well on 39, 45, 46
- McCook, gas in well at 26
  - wells at 26, 43, 48, 49
- Macon, wells near 53
- Map of Nebraska, showing area treated 7
- Map, geologic, of Republican and Little Blue valleys 10
- Max, elephant bones near 24
- Medicine Creek, description of 35
  - water power on 59–60
- Meridian, dam near 60
- Mineral paint, occurrence and character of 30–31
- Mineral resources, description of 25–31
  - *See also particular minerals.*
- Moline, wells at 53
- Moose ranch, springs on 36
- Mortar beds, building stone from 27
  - view of 20
- Mules and horses, number and distribution of 65

N.

- Naponee, water power at 60
  - wells at 53
- Nebraska, map of 7
  - sections across 12
- Nelson, wells at 55
- Niobrara formation, building stone from 27
  - ocher in 30–31
  - occurrence and character of 17–18
  - use of, in cement manufacture 28
  - view of 14, 26
    - water of 43
    - quality of 38
- Norton, fault near 11
  - fault near, view of 14
- Nuckolls County, building stone in 27
  - crops in 63, 64
  - geology in 17, 18
  - stock raising in 65
  - water resources of 55

O.

- Oak, dam near 60
- Ocher, occurrence of 30–31
- Odell, section near 12
- Ogalalla formation, correlation of 19
- Orleans, volcanic ash at 30
  - water power at 59
- Ostrea congesta 16
- Oxford, water power at 59
  - wells near 50

P.

- Paint, mineral, occurrence and character of 30–31
- Palisade, flow of Frenchman River at 35
  - water power at 59

Page.

Permian rocks, occurrence and character of 11-12
  wells to 44
Petroleum, possible occurrence of 26
Pierre shale, coal in 26
  occurrence and character of 18-19
  oil and gas in 26
  use of, in cement manufacture 28
  water of, quality of 38, 45
Plaster, manufacture of 29
Pleistocene deposits, sand and gravel from. 29
  springs from 36
Pollution of wells, danger of 42-43
Ponds, occurrence of 37
Portland cement, materials for and manufacture of 28
Powell, coal near 25
  sand and gravel near 29
  wells near 57
Prairie Dog Creek, description of 35

Q.

Quartzite, occurrence and description of 27-28
  view of 22
Quaternary deposits, base of, springs at 36
  occurrence and character of 10, 20-25
  water capacity of 38
  water in 39

R.

Rainfall, records of 9-10
  westward decrease of, diagram showing. 9
Red Cloud, rainfall at 10
  sand and gravel near 29
  water power at 59
  wells near 54
Redwillow, water power at 59
  well near 49
Redwillow County, crops in 63
  irrigation in 61
  stock raising in 65
  water resources of 48-49
Redwillow Creek, descripton of 35
Reiter, J. P., and Smith, Adolph, ocher mined by 31
Republican River, building stone on 27-28
  character of 8, 32, 46
  dam in, view of 46
  discharge data of 32-34
  irrigation along 60
  power sites on 59-60
  sand and gravel on 28
  source, course, and tributaries of 31-32
  springs along 36
  valley of, geologic map of 10
  view on 32
Rivers and creeks, descriptions of 31-36
Riverton, wells near 53
Rock Creek, water power on 59
Rocks, occurrence and character of 10-25
Rosemont, wells near 54

S.

Sand, occurrence of 28-30
Sandhill Lake, view of 32
Sand hills, agriculture on 62
  occurrence and character of 8, 23
  ponds in 37
  view of 26
  windmill in, view of 44
Sappa Creek, description of 35
  water power on 60
Septarian zone, occurrence of 16
Smith, Adolph, and Reiter, J. P., ocher mined by 31
Smoky Hill chalk, correlative of 17
Soils, occurrence and character of 61-62
Springs, distribution of 47
  in Furnas County 50
  in Harlan County 52
  in Nuckolls County 55
  in Redwillow County 49
  in Webster County 54
  origin of 36-37
  view of 34
Stamford, flow at 35
  water power at 60
Steele, clay near 28
  dam near 60
  section near 13
  wells near 44, 57
Stevens, J. C., data from 32
Stipa conata, occurrence of 63
Stock raising, practice of 65
Stone, artificial, manufacture of 29-30
Stone, building, occurrence and character of. 26-28
Stratigraphy, description of 10-25
Structure, description of 11
Sugar beets, cultivation of 65
Superior, dam at, view of 46
  rainfall at 10
  sand and gravel near 29
  water power at 59
  wells near 55
Surface waters. *See* Waters, surface.

T.

Temperature, records of 9
Terraces, occurrence and character of 23-24
  view of 24
Tertiary deposits, building stone from 27
  occurrence and character of 10, 19-20
  sand and gravel in 29
  section of 20
  springs at base of 36
  view of 20
  water in 39, 44
    quality of 38
  water capacity of 38
Thayer County, building stone in 27
  crops in 63, 64
  geology in 21, 56
  stock raising in 65
  water resources of 55-57
Timber, occurrence and character of 66
  view of 60
Topography, description of 8
Trail Canyon, character of 8
  gravel in, view of 20
  terraces near, view of 24

Page.
Trees, acclimatization of 61
  distribution and kinds of 66
Trenton, sand and gravel near 29
  springs near 36, 47
  wells near 41

U.

Underground waters. *See* Waters, underground.

V.

Volcanic ash, analysis of 30
  character and uses of 30

W.

Water power, description of 58-61
Water resources, description of 31-61
  description of, by counties 45-58
Water table, level of 38
Waters, surface, character of 31
  description of 31-37
  storage of 37
Waters, underground, conditions of, figure illustrating 40
  depletion of 38-39
  occurrence of, figure showing 40
  quality of 38
  source of 37-38
Wauneta, falls near 34

Page.
Wauneta, falls near, view of 34
  water power at 59
Webster County, crops in 63, 64
  ocher in 30
  stock raising in 65
  water resources of 54
Weeks, C. E., blowing well on ranch of 42
Wells, artesian, location of 26, 43-45
  prospects for 44
  view of 46
Wells, blowing, conditions causing 41-42
  conditions causing, figure illustrating 41
  freezing of 42
Wells, George, blowing well of 42
Wells, shallow, data on 45-58
  description of 39
  irrigation from 43
  pollution of 42-43
  yield of 39-41
  See also particular counties, owners, etc.
Wilsonville, water power at 60
  wells near 50
Wind erosion, effects of, view illustrating 24
Windmills, pumping by 43
  view of 44
Winds, character of 10
Woodruff, Kans., quarry at 27

Z.

Zike, S. C., volcanic ash mined by 30

CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 216.]

The publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists can be had on application.

Most of the above publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained, free of charge (except classes 2, 7, and 8), on application.
2. A certain number are delivered to Senators and Representatives in Congress for distribution.
3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost.
4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they can be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports; Q, Fuels; R, Structural materials. This paper is the ninety-seventh in series A, the one hundred and nineteenth in series B, the twenty-sixth in series M, and the seventy-second in series O, the complete lists of which follow (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper).

SERIES A, ECONOMIC GEOLOGY.

B 21. Lignites of Great Sioux Reservation: Report on region between Grand and Moreau rivers, Dakota, by Bailey Willis. 1885. 16 pp., 5 pls. (Out of stock.)

B 46. Nature and origin of deposits of phosphate of lime, by R. A. F. Penrose, jr., with introduction by N. S. Shaler. 1888. 143 pp. (Out of stock.)

B 65. Stratigraphy of the bituminous coal field of Pennsylvania, Ohio, and West Virginia, by I. C. White. 1891. 212 pp., 11 pls. (Out of stock.)

B 111. Geology of Big Stone Gap coal field of Virginia and Kentucky, by M. R. Campbell. 1893. 106 pp., 6 pls. (Out of stock.)

B 132. The disseminated lead ores of southeastern Missouri, by Arthur Winslow. 1896. 31 pp. (Out of stock.)

B 138. Artesian-well prospects in Atlantic Coastal Plain region, by N. H. Darton. 1896. 228 pp., 19 pls.

B 139. Geology of Castle Mountain mining district, Montana, by W. H. Weed and L. V. Pirsson. 1896. 164 pp., 17 pls.

B 143. Bibliography of clays and the ceramic arts, by J. C. Branner. 1896. 114 pp.

B 164. Reconnaissance on the Rio Grande coal fields of Texas, by T. W. Vaughan, including a report on igneous rocks from the San Carlos coal field, by E. C. E. Lord. 1900. 100 pp., 11 pls. (Out of stock.)

B 178. El Paso tin deposits, by W. H. Weed. 1901. 15 pp., 1 pl.

B 180. Occurrence and distribution of corundum in United States, by J. H. Pratt. 1901. 98 pp., 14 pls. (Out of stock; see No. 269.)

B 182. A report on the economic geology of the Silverton quadrangle, Colorado, by F. L. Ransome. 1901. 266 pp., 16 pls. (Out of stock.)

B 184. Oil and gas fields of the western interior and northern Texas Coal Measures and of the Upper Cretaceous and Tertiary of the western Gulf coast, by G. I. Adams. 1901. 64 pp., 10 pls. (Out of stock.)

B 193. The geological relations and distribution of platinum and associated metals, by J. F. Kemp. 1902. 95 pp., 6 pls.

B 198. The Berea grit oil sand in the Cadiz quadrangle, Ohio, by W. T. Griswold. 1902. 43 pp., 1 pl. (Out of stock.)

PP 1. Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by A. H. Brooks. 1902. 120 pp., 2 pls.

B 200. Reconnaissance of the borax deposits of Death Valley and Mohave Desert, by M. R. Campbell. 1902. 23 pp., 1 pl. (Out of stock.)

B 202. Tests for gold and silver in shales from western Kansas, by Waldemar Lindgren. 1902. 21 pp. (Out of stock.)

PP 2. Reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. 1902. 70 pp., 11 pls.

PP 10. Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. 1902. 68 pp., 10 pls.

PP 11. Clays of the United States east of the Mississippi River, by Heinrich Ries. 1903. 298 pp., 9 pls. (Out of stock.)

PP 12. Geology of the Globe copper district, Arizona, by F. L. Ransome. 1903. 168 pp., 27 pls.

B 212. Oil fields of the Texas-Louisiana Gulf Coastal Plain, by C. W. Hayes and William Kennedy. 1903. 174 pp., 11 pls. (Out of stock.)

B 213. Contributions to economic geology, 1902; S. F. Emmons and C. W. Hayes, geologists in charge. 1903. 449 pp. (Out of stock.)

PP 15. The mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall and F. C. Schrader. 1903. 71 pp., 10 pls.

B 218. Coal resources of the Yukon, Alaska, by A. J. Collier. 1903. 71 pp., 6 pls.

B 219. The ore deposits of Tonopah, Nevada (preliminary report), by J. E. Spurr. 1903. 31 pp., 1 pl. (Out of stock.)

PP 20. A reconnaissance in northern Alaska in 1901, by F. C. Schrader. 1904. 139 pp., 16 pls.

PP 21. Geology and ore deposits of the Bisbee quadrangle, Arizona, by F. L. Ransome. 1904. 168 pp., 29 pls.

B 223. Gypsum deposits in the United States, by G. I. Adams and others. 1904. 129 pp., 21 pls. (Out of stock.)

PP 24. Zinc and lead deposits of northern Arkansas, by G. I. Adams. 1904. 118 pp., 27 pls.

PP 25. Copper deposits of the Encampment district, Wyoming, by A. C. Spencer. 1904. 107 pp., 2 pls. (Out of stock.)

B 225. Contributions to economic geology, 1903, by S. F. Emmons and C. W. Hayes, geologists in charge. 1904. 527 pp., 1 pl. (Out of stock.)

PP 26. Economic resources of the northern Black Hills, by J. D. Irving, with contributions by S. F. Emmons and T. A. Jaggar, jr. 1904. 222 pp., 20 pls.

PP 27. A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho, by Waldemar Lindgren. 1904. 123 pp., 15 pls.

B 229. Tin deposits of the York region, Alaska, by A. J. Collier. 1904. 61 pp., 7 pls.

B 236. The Porcupine placer district, Alaska, by C. W. Wright. 1904. 35 pp., 10 pls.

B 238. Economic geology of the Iola quadrangle, Kansas, by G. I. Adams, Erasmus Haworth, and W. R. Crane. 1904. 83 pp., 11 pls.

B 243. Cement materials and industry of the United States, by E. C. Eckel. 1905. 395 pp., 15 pls.

B 246. Zinc and lead deposits of northwestern Illinois, by H. Foster Bain. 1904. 56 pp., 5 pls.

B 247. The Fairhaven gold placers of Seward Peninsula, Alaska, by F. H. Moffit. 1905. 85 pp., 14 pls.

B 249. Limestones of southeastern Pennsylvania, by F. G. Clapp. 1905. 52 pp., 7 pls.

B 250. The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. 1905. 65 pp., 7 pls.

B 251. The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska, by L. M. Prindle. 1905. 89 pp., 16 pls.

WS 117. The lignite of North Dakota and its relation to irrigation, by F. A. Wilder. 1905. 59 pp., 8 pls.

PP 36. The lead, zinc, and fluorspar deposits of western Kentucky, by E. O. Ulrich and W. S. T. Smith. 1905. 218 pp., 15 pls.

PP 38. Economic geology of the Bingham mining district, Utah, by J. M. Boutwell, with a chapter on areal geology, by Arthur Keith, and an introduction on general geology, by S. F. Emmons. 1905. 413 pp., 49 pls.

PP 41. Geology of the central Copper River region, Alaska, by W. C. Mendenhall. 1905. 133 pp., 20 pls.

B 254. Report of progress in the geological resurvey of the Cripple Creek district, Colorado, by Waldemar Lindgren and F. L. Ransome. 1904. 36 pp.

B 255. The fluorspar deposits of southern Illinois, by H. Foster Bain. 1905. 75 pp., 6 pls. (Out of stock.)

B 256. Mineral resources of the Elders Ridge quadrangle, Pennsylvania, by R. W. Stone. 1905. 86 pp., 12 pls.

B 259. Report on progress of investigations of mineral resources of Alaska in 1904, by A. H. Brooks and others. 1905. 196 pp., 3 pls.

B 260. Contributions to economic geology, 1904; S. F. Emmons and C. W. Hayes, geologists in charge. 1905. 620 pp., 4 pls.

B 261. Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, and M. R. Campbell, committee in charge. 1905. 172 pp. (Out of stock.)

B 263. Methods and cost of gravel and placer mining in Alaska, by C. W. Purington. 1905. 273 pp., 42 pls. (Out of stock.)

PP 42. Geology of the Tonopah mining district, Nevada, by J. E. Spurr. 1905. 295 pp., 24 pls.

PP 43. The copper deposits of the Clifton-Morenci district, Arizona, by Waldemar Lindgren. 1905. 375 pp., 25 pls.

B 264. Record of deep-well drilling for 1904, by M. L. Fuller, E. F. Lines, and A. C. Veatch. 1905. 106 pp.

B 265. Geology of the Boulder district, Colorado, by N. M. Fenneman. 1905. 101 pp., 5 pls.

B 267. The copper deposits of Missouri, by H. Foster Bain and E. O. Ulrich. 1905. 52 pp., 1 pl.

B 269. Corundum and its occurrence and distribution in the United States (a revised and enlarged edition of Bulletin No. 180), by J. H. Pratt. 1906. 175 pp., 18 pls.

PP 48. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1906. (In three parts.) 1,492 pp., 13 pls.

B 275. Slate deposits and slate industry of the United States, by T. N. Dale, with sections by E. C. Eckel, W. F. Hillebrand, and A. T. Coons. 1906. 154 pp., 25 pls.

PP 49. Geology and mineral resources of part of the Cumberland Gap coal field, Kentucky, by G. H. Ashley and L. C. Glenn, in cooperation with the State Geological Department of Kentucky, C. J. Norwood, curator. 1906. 239 pp., 40 pls.

B 277. Mineral resources of Kenai Peninsula, Alaska: Gold fields of the Turnagain Arm region, by F. H. Moffit; Coal fields of the Kachemak Bay region, by R. W. Stone. 1906. 80 pp., 18 pls,

B 278. Geology and coal resources of the Cape Lisburne region, Alaska, by A. J. Collier. 1906. 54 pp., 9 pls. (Out of stock.)

B 279. Mineral resources of the Kittanning and Rural Valley quadrangles, Pennsylvania, by Charles Butts. 1906. 198 pp., 11 pls.

B 280. The Rampart gold placer region, Alaska, by L. M. Prindle and F. L. Hess. 1906. 54 pp., 7 pls. (Out of stock.)

B 282. Oil fields of the Texas-Louisiana Gulf Coastal Plain, by N. M. Fenneman. 1906. 146 pp., 11 pls.

PP 51. Geology of the Bighorn Mountains, by N. H. Darton. 1906. 129 pp., 47 pls.

B 283. Geology and mineral resources of Mississippi, by A. F. Crider. 1906. 99 pp., 4 pls.

B 284. Report on progress of investigations of the mineral resources of Alaska in 1905, by A. H. Brooks and others. 1906. 169 pp., 14 pls.

B 285. Contributions to economic geology, 1905; S. F. Emmons and E. C. Eckel, geologists in charge. 1906. 506 pp., 13 pls. (Out of stock.)

B 286. Economic geology of the Beaver quadrangle, Pennsylvania, by L. H. Woolsey. 1906. 132 pp., 8 pls.

B 287. Juneau gold belt, Alaska, by A. C. Spencer, and A reconnaissance of Admiralty Island, Alaska, by C. W. Wright. 1906. 161 pp., 27 pls.

PP 54. The geology and gold deposits of the Cripple Creek district, Colorado, by W. Lindgren and F. L. Ransome. 1906. 516 pp., 29 pls.

PP 55. Ore deposits of the Silver Peak quadrangle, Nevada, by J. E. Spurr. 1906. 174 pp., 24 pls.

B 289. A reconnaissance of the Matanuska coal field, Alaska, in 1905, by G. C. Martin. 1906. 34 pp., 5 pls.

B 290. Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905, by J. A. Holmes. 1906. 240 pp.

B 293. Reconnaissance of some gold and tin deposits of the southern Appalachians, by L. C. Graton, with notes on the Dahlonega mines, by W. Lindgren. 1906. 134 pp., 9 pls.

B 294. Zinc and lead deposits of the upper Mississippi Valley, by H. Foster Bain. 1906. 155 pp., 16 pls.

B 295. The Yukon-Tanana region, Alaska, description of Circle quadrangle, by L. M. Prindle. 1906. 27 pp., 1 pl.

B 296. Economic geology of the Independence quadrangle, Kansas, by Frank C. Schrader and Erasmus Haworth. 1906. 74 pp., 6 pls.

B 297. The Yampa coal field, Routt County, Colo., by N. M. Fenneman, Hoyt S. Gale, and M. R. Campbell. 1906. 96 pp., 9 pls.

B 298. Record of deep-well drilling for 1905, by Myron L. Fuller and Samuel Sanford. 1906. 299 pp.

B 300. Economic geology of the Amity quadrangle in eastern Washington County, Pa., by Frederick G. Clapp. 1907. 145 pp., 8 pls.

B 303. Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada, by F. L. Ransome, with notes on Manhattan district, by G. H. Garrey and W. H. Emmons. 1906. 98 pp., 5 pls.

B. 304. Oil and gas fields of Greene County, Pa., by R. W. Stone and Frederick G. Clapp. 1906. 110 pp., 3 pls.

PP 56. Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil, by A. C. Veatch. 1907. — pp., 26 pls.

B 308. A geologic reconnaissance in southwestern Nevada and eastern California, by S. H. Ball. 1907. 218 pp., 3 pls.

B 309. The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California, by G. H. Eldridge and Ralph Arnold. 1907. 266 pp., 41 pls.

B 312. The interaction between minerals and water solutions, with special reference to geologic phenomena, by E. C. Sullivan. 1907. 69 pp.

B 313. The granites of Maine, by T. Nelson Dale, with an introduction by G. O. Smith. 1907. — pp., 14 pls.

B 314. Report of progress of investigations of mineral resources of Alaska in 1906, by A. H. Brooks and others. 1907. 235 pp., 4 pls.

B 315. Contributions to economic geology, 1906, Part I: Metals and nonmetals, except fuels; S. F. Emmons and E. C. Eckel, geologists in charge. 1907. 504 pp., 4 pls.

WS 215. Geology and water resources of a portion of the Missouri River Valley in northeastern Nebraska, by G. E. Condra. 1908. — pp., 11 pls.

WS 216. Geology and water resources of the Republican River Valley in Nebraska and adjacent areas, by G. E. Condra. 1907. 71 pp., 13 pls.

SERIES B, DESCRIPTIVE GEOLOGY.

B 23. Observations on the junction between the Eastern sandstone and the Keweenaw series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 124 pp., 17 pls. (Out of stock.)

B 33. Notes on geology of northern California, by J. S. Diller. 1886. 23 pp. (Out of stock.)

B 39. The upper beaches and deltas of Glacial Lake Agassiz, by Warren Upham. 1887. 84 pp., 1 pl. (Out of stock.)

B 40. Changes in river courses in Washington Territory due to glaciation, by Bailey Willis. 1887. 10 pp., 4 pls. (Out of stock.)

B 45. The present condition of knowledge of the geology of Texas, by R. T. Hill. 1887. 94 pp. (Out of stock.)

B 53. The geology of Nantucket, by N. S. Shaler. 1889. 55 pp., 10 pls. (Out of stock.)

B 57. A geological reconnaissance in southwestern Kansas, by Robert Hay. 1890. 49 pp., 2 pls.

B 58. The glacial boundary in western Pennsylvania, Ohio, Kentucky, Indiana, and Illinois, by G. F. Wright, with introduction by T. C. Chamberlin. 1890. 112 pp., 8 pls. (Out of stock.)

B 67. The relations of the traps of the Newark system in the New Jersey region, by N. H. Darton. 1890. 82 pp. (Out of stock.)

B 104. Glaciation of the Yellowstone Valley north of the Park, by W. H. Weed. 1893. 41 pp., 4 pls.

B 108. A geological reconnaissance in central Washington, by I. C. Russell. 1893. 108 pp., 12 pls. (Out of stock.)

B 119. A geological reconnaissance in northwest Wyoming, by G. H. Eldridge. 1894. 72 pp., 4 pls.

B 137. The geology of the Fort Riley Military Reservation and vicinity, Kansas, by Robert Hay. 1896. 35 pp., 8 pls.

B 144. The moraines of the Missouri Coteau and their attendant deposits, by J. E. Todd. 1896. 71 pp., 21 pls.

B 158. The moraines of southeastern South Dakota and their attendant deposits, by J. E. Todd. 1899. 171 pp., 27 pls.

B 159. The geology of eastern Berkshire County, Massachusetts, by B. K. Emerson. 1899. 139 pp., 9 pls.

B 165. Contributions to the geology of Maine, by H. S. Williams and H. E. Gregory. 1900. 212 pp., 14 pls.

WS 70. Geology and water resources of the Patrick and Goshen Hole quadrangles in eastern Wyoming and western Nebraska, by G. I. Adams. 1902. 50 pp., 11 pls.

B 199. Geology and water resources of the Snake River Plains of Idaho, by I. C. Russell. 1902. 192 pp., 25 pls.

PP 1. Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by A. H. Brooks. 1902. 120 pp., 2 pls.

PP 2. Reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. 1902. 70 pp., 11 pls.

PP 3. Geology and petrography of Crater Lake National Park, by J. S. Diller and H. B. Patton. 1902. 167 pp., 19 pls.

PP 10. Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. 1902. 68 pp., 10 pls.

PP 11. Clays of the United States east of the Mississippi River, by Heinrich Ries. 1903. 298 pp., 9 pls. (Out of stock.)

PP 12. Geology of the Globe copper district, Arizona, by F. L. Ransome. 1903. 168 pp., 27 pls.

PP 13. Drainage modifications in southeastern Ohio and adjacent parts of West Virginia and Kentucky, by W. G. Tight. 1903. 111 pp., 17 pls. (Out of stock.)

B 208. Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California, by J. E. Spurr. 1903. 229 pp., 8 pls. (Out of stock.)

B 209. Geology of Ascutney Mountain, Vermont, by R. A. Daly. 1903. 122 pp., 7 pls.

WS 78. Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon, by I. C. Russell. 1903. 51 pp., 2 pls.

PP 15. Mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall and F. C. Schrader. 1903. 71 pp., 10 pls.

PP 17. Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian, by N. H. Darton. 1903. 69 pp., 43 pls.

B 217. Notes on the geology of southwestern Idaho and southeastern Oregon, by I. C. Russell. 1903. 83 pp., 18 pls.

B 219. The ore deposits of Tonopah, Nevada (preliminary report), by J. E. Spurr. 1903. 31 pp., 1 pl.

PP 20. A reconnaissance in northern Alaska in 1901, by F. C. Schrader. 1904. 139 pp., 16 pls.

PP 21. The geology and ore deposits of the Bisbee quadrangle, Arizona, by F. L. Ransome. 1904. 168 pp., 29 pls.

WS 90. Geology and water resources of part of the lower James River Valley, South Dakota, by J. E. Todd and C. M. Hall. 1904. 47 pp., 23 pls.

PP 25. The copper deposits of the Encampment district, Wyoming, by A. C. Spencer. 1904. 107 pp., 2 pls. (Out of stock.)

PP 26. Economic resources of the northern Black Hills, by J. D. Irving, with contributions by S. F. Emmons and T. A. Jaggar, jr. 1904. 222 pp., 20 pls.

PP 27. A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho, by Waldemar Lindgren. 1904. 122 pp., 15 pls.

PP 31. Preliminary report on the geology of the Arbuckle and Wichita mountains in Indian Territory and Oklahoma, by J. A. Taff, with an appendix on reported ore deposits in the Wichita Mountains, by H. F. Bain. 1904. 97 pp., 8 pls.

B 235. A geological reconnaissance across the Cascade Range near the forty-ninth parallel, by G. O. Smith and F. C. Calkins. 1904. 103 pp., 4 pls.

B 236. The Porcupine placer district, Alaska, by C. W. Wright. 1904. 35 pp., 10 pls.

B 237. Igneous rocks of the Highwood Mountains, Montana, by L. V. Pirsson. 1904. 208 pp., 7 pls.

B 238. Economic geology of the Iola quadrangle, Kansas, by G. I. Adams, Erasmus Haworth, and W. R. Crane. 1904. 83 pp., 1 pl.

PP 32. Geology and underground water resources of the central Great Plains, by N. H. Darton. 1905. 433 pp., 72 pls.

WS 110. Contributions to hydrology of eastern United States, 1904; M. L. Fuller, geologist in charge, 1905. 211 pp., 5 pls.

B 242. Geology of the Hudson Valley between the Hoosic and the Kinderhook, by T. Nelson Dale, 1904. 63 pp., 3 pls.

PP 34. The Delavan lobe of the Lake Michigan glacier of the Wisconsin stage of glaciation and associated phenomena, by W. C. Alden. 1904. 106 pp., 15 pls.

PP 35. Geology of the Perry Basin in southeastern Maine, by G. O. Smith and David White. 1905. 107 pp., 6 pls.

B 243. Cement materials and industry of the United States, by E. C. Eckel. 1905. 395 pp., 15 pls.

B 246. Zinc and lead deposits of northeastern Illinois, by H. F. Bain. 1904. 56 pp., 5 pls.

B 247. The Fairhaven gold placers of Seward Peninsula, Alaska, by F. H. Moffit. 1905. 85 pp., 14 pls.

B 249. Limestones of southwestern Pennsylyania, by F. G. Clapp. 1905. 52 pp., 7 pls.

B 250. The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposit, by G. C. Martin. 1905. 65 pp., 7 pls.

B 251. The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska, by L. M. Prindle. 1905. 16 pp., 16 pls.

WS 118. Geology and water resources of a portion of east-central Washington, by F. C. Calkins. 1905. 96 pp., 4 pls.

B 252 Preliminary report on the geology and water resources of central Oregon, by I. C. Russell. 1905. 138 pp., 24 pls.

PP 36. The lead, zinc, and fluorspar deposits of western Kentucky, by E. O. Ulrich and W. S. Tangier Smith. 1905. 218 pp., 15 pls.

PP 38. Economic geology of the Bingham mining district of Utah, by J. M. Boutwell, with a chapter on areal geology, by Arthur Keith, and an introduction on general geology, by S. F. Emmons. 1905. 413 pp., 49 pls.

PP 41. The geology of the central Copper River region, Alaska, by W. C. Mendenhall. 1905. 133 pp., 20 pls.

B 254. Report of progress in the geological resurvey of the Cripple Creek district, Colorado, by Waldemar Lindgren and F. L. Ransome. 1904. 36 pp.

B 255. The fluorspar deposits of southern Illinois, by H. Foster Bain. 1905. 75 pp., 6 pls. (Out of stock.)

B 256. Mineral resources of the Elders Ridge quadrangle, Pennsylvania, by R. W. Stone. 1905. 85 pp., 12 pls.

B 257. Geology and paleontology of the Judith River beds, by T. W. Stanton and J. B. Hatcher, with a chapter on the fossil plants, by F. H. Knowlton. 1905. 174 pp., 19 pls.

PP 42. Geology of the Tonopah mining district, Nevada, by J. E. Spurr. 1905. 295 pp., 24 pls.

WS 123. Geology and underground water conditions of the Jornada del Muerto, New Mexico, by C. R. Keyes. 1905. 42 pp., 9 pls. (Out of stock.)

WS 136. Underground waters of Salt River Valley, Arizona, by W. T. Lee. 1905. 194 pp., 24 pls.

PP 43. The copper deposits of Clifton-Morenci, Arizona, by Waldemar Lindgren. 1905. 375 pp., 25 pls.

B 265. Geology of the Boulder district, Colorado, by N. M. Fenneman. 1905. 101 pp., 5 pls.

B 267. The copper deposits of Missouri, by H. F. Bain and E. O. Ulrich. 1905. 52 pp., 1 pl.

PP 44. Underground water resources of Long Island, New York, by A. C. Veatch and others. 1905. 394 pp., 34 pls.

WS 148. Geology and water resources of Oklahoma, by C. N. Gould. 1905. 178 pp., 22 pls.

B 270. The configuration of the rock floor of Greater New York, by W. H. Hobbs. 1905. 96 pp., 5 pls.

B 272. Taconic physiography, by T. M. Dale. 1905. 52 pp., 14 pls.

PP 45. The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. V. Goode. 1905. 327 pp., 34 pls.

B 273. The drumlins of southeastern Wisconsin (preliminary paper), by W. C. Alden. 1905. 46 pp., 9 pls.

PP 46. Geology and underground water resources of northern Louisiana and southern Arkansas, by A. C. Veatch. 1906. 422 pp., 51 pls.

PP 49. Geology and mineral resources of part of the Cumberland Gap coal field, Kentucky, by G. H. Ashley and L. C. Glenn, in cooperation with the State Geological Department of Kentucky, C. J. Norwood, curator. 1906. 239 pp., 40 pls.

PP 50. The Montana lobe of the Keewatin ice sheet, by F. H. H. Calhoun. 1906. 62 pp., 7 pls.

B 277. Mineral resources of Kenai peninsula, Alaska: Gold fields of the Turnagain Arm region, by F. H. Moffit; and the coal fields of the Kachemak Bay region, by R. W. Stone. 1906. 80 pp., 18 pls. (Out of stock.)

WS 154. The geology and water resources of the eastern portion of the Panhandle of Texas, by C. N. Gould. 1906. 64 pp., 15 pls.

B 278. Geology and coal resources of the Cape Lisburne region, Alaska, by A. J. Collier. 1906. 54 pp., 9 pls. (Out of stock.)

B 279. Mineral resources of the Kittanning and Rural Valley quadrangles, Pennsylvania, by Charles Butts. 1906. 198 pp., 11 pls.

B 280. The Rampart gold placer region, Alaska, by L. M. Prindle and F. L. Hess. 1906. 54 pp., 7 pls. (Out of stock.)

B 282. Oil fields of the Texas-Louisiana Gulf Coastal Plain, by N. M. Fenneman. 1906. 146 pp., 11 pls.

WS 157. Underground water in the valleys of Utah Lake and Jordan River, Utah, by G. B. Richardson. 1906. 81 pp., 9 pls.

PP 51. Geology of the Bighorn Mountains, by N. H. Darton. 1906. 129 pp., 47 pls.

WS 158. Preliminary report on the geology and underground waters of the Roswell artesian area, New Mexico, by C. A. Fisher. 1906. 29 pp., 9 pls.

PP 52. Geology and underground waters of the Arkansas Valley in eastern Colorado, by N. H. Darton. 1906. 90 pp., 28 pls.

WS 159. Summary of underground-water resources of Mississippi, by A. F. Crider and L. C. Johnson. 1906. 86 pp., 6 pls.

PP 53. Geology and water resources of the Bighorn basin, Wyoming, by C. A. Fisher. 1906. 72 pp. 16 pls.

B 283. Geology and mineral resources of Mississippi, by A. F. Crider. 1906. 99 pp., 4 pls.

B 286. Economic geology of the Beaver quadrangle, Pennsylvania (southern Beaver and northwestern Allegheny counties), by L. H. Woolsey. 1906. 132 pp., 8 pls.

B 287. The Juneau gold belt, Alaska, by A. C. Spencer, and a reconnaissance of Admiralty Island, Alaska, by C. W. Wright. 1906. 161 pp., 37 pls.

PP 54. The geology and gold deposits of the Cripple Creek district, Colorado, by W. Lindgren and F. L. Ransome. 1906. 516 pp., 29 pls.

PP 55. Ore deposits of the Silver Peak quadrangle, Nevada, by J. E. Spurr. 1906. 174 pp., 24 pls.
B 289. A reconnaissance of the Matanuska coal field, Alaska, in 1905, by G. C. Martin. 1906. 36 pp., 5 pls.
WS 164. Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois, by L. C. Glenn. 1906. 173 pp., 7 pls.
B 293. Reconnaissance of some gold and tin deposits of the southern Appalachians, by L. C. Graton, with notes on the Dahlonega mines, by W. Lindgren. 1906. 134 pp., 9 pls.
B 294. Zinc and lead deposits of the upper Mississippi Valley, by H. Foster Bain. 1906. 155 pp., 16 pls.
B 295. The Yukon-Tanana region, Alaska, description of Circle quadrangle, by L. M. Prindle. 1906. 27 pp., 1 pl.
B 296. Economic geology of the Independence quadrangle, Kansas, by Frank C. Schrader and Erasmus Haworth. 1906. 74 pp., 6 pls.
WS 181. Geology and water resources of Owens Valley, California, by Willis T. Lee. 1906. 28 pp., 6 pls.
B 297. The Yampa coal field, Routt County, Colo., by N. M. Fenneman, Hoyt S. Gale, and M. R. Campbell. 1906. 96 pp., 9 pls.
B 300. Economic geology of the Amity quadrangle in eastern Washington County, Pa., by F. G. Clapp. 1906. 145 pp., 8 pls.
B 303. Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada, by F. L. Ransome; with notes on the Manhattan district, by G. H. Garrey and W. H. Emmons. 1907. 98 pp., 5 pls.
B 304. Oil and gas fields of Greene County, Pa., by Ralph W. Stone and Frederick G. Clapp. 1906. 110 pp., 3 pls.
WS 188. Water resources of the Rio Grande Valley in New Mexico and their development, by W. T. Lee. 1906. 59 pp., 10 pls.
B 306. Rate of recession of Niagara Falls, by G. K. Gilbert, accompanied by a report on the survey of the crest, by W. Carvel Hall. 1906. 31 pp., 11 pls.
PP 56. Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil, by A. C. Veatch. 1907. — pp., 26 pls.
B 308. A geologic reconnaissance in southwestern Nevada and eastern California, by S. H. Ball. 1907. 218 pp., 3 pls.
B 309. The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California, by G. H. Eldridge and Ralph Arnold. 1907. 266 pp., 41 pls.
PP 57. Geology of the Marysville mining district, Montana, a study of igneous intrusion and contact metamorphism, by Joseph Barrell. 1907. 178 pp., 16 pls.
WS 191. The geology and water resources of the western portion of the Panhandle of Texas, by C. N. Gould. 1907. 70 pp., 7 pls.
B 311. The green schists and associated granites and porphyries of Rhode Island, by B. K. Emerson and J. H. Perry. 1907. 74 pp., 2 pls.
WS 195. Underground waters of Missouri, their geology and utilization, by Edward Shepard. 1907. 224 pp., 6 pls.
WS 199. Underground water in Sanpete and central Sevier valleys, Utah, by G. B. Richardson. 1907. 63 pp., 6 pls.
WS 215. Geology and water resources of a portion of the Missouri River Valley in northeastern Nebraska, by G. E. Condra. 1908. — pp., 11 pls.
WS 216. Geology and water resources of the Republican River Valley in Nebraska and adjacent areas, by G. E. Condra. 1907. 71 pp., 13 pls.

SERIES M, GENERAL HYDROGRAPHIC INVESTIGATIONS.

WS 56. Methods of stream measurement. 1901. 51 pp., 12 pls.
WS 64. Accuracy of stream measurements, by E. C. Murphy. 1902. 99 pp., 4 pls.
WS 76. Observations on the flow of rivers in the vicinity of New York City, by H. A. Pressey. 1902. 108 pp., 13 pls.
WS 80. The relation of rainfall to run-off, by G. W. Rafter. 1903. 104 pp.
WS 81. California hydrography, by J. B. Lippincott. 1903. 488 pp., 1 pl.
WS 88. The Passaic flood of 1902, by G. B. Hollister and M. O. Leighton. 1903. 56 pp., 15 pls.
WS 91. Natural features and economic development of the Sandusky, Maumee, Muskingum, and Miami drainage areas in Ohio, by B. H. Flynn and M. S. Flynn. 1904. 130 pp.
WS 92. The Passaic flood of 1903, by M. O. Leighton. 1904. 48 pp., 7 pls.
WS 94. Hydrographic manual of the United States Geological Survey, prepared by E. C. Murphy, J. C. Hoyt, and G. B. Hollister. 1904. 76 pp., 3 pls. (Out of stock.)
WS 95. Accuracy of stream measurements (second edition), by E. C. Murphy. 1904. 169 pp., 6 pls.
WS 96. Destructive floods in the United States in 1903, by E. C. Murphy. 1904. 81 pp., 13 pls.
WS 106. Water resources of the Philadelphia district, by Florence Bascom. 1904. 75 pp., 4 pls.
WS 109. Hydrography of the Susquehanna River drainage basin, by J. C. Hoyt and R. H. Anderson. 1904. 215 pp., 28 pls.
WS 116. Water resources near Santa Barbara, California, by J. B. Lippincott. 1904. 99 pp., 8 pls.

WS 147. Destructive floods in the United States in 1904, by E. C. Murphy and others. 1905. 206 pp., 18 pls.

WS 150. Weir experiments, coefficients, and formulas, by R. E. Horton. 1906. 189 pp., 38 pls. (Out of stock.)

WS 162. Destructive floods in the United States in 1905, by E. C. Murphy and others. 1906. 105 pp., 4 pls.

WS 180. Turbine water-wheel tests and power tables, by Robert E. Horton. 1906. 134 pp., 2 pls. (Out of stock.)

WS 187. Determination of stream flow during the frozen season, by H. K. Barrows and Robert E. Horton. 1907. 93 pp., 1 pl.

WS 192. The Potomac River basin: Geographic history—rainfall and stream flow—pollution, typhoid fever, and character of water—relation of soils and forest cover to quality and quantity of surface water—effect of industrial wastes on fishes, by H. N. Parker, Bailey Willis, R. H. Bolster, W. W. Ashe, and M. C. Marsh. 1907. 364 pp., 10 pls.

WS 196. Water supply of Nome region, Seward Peninsula, Alaska, 1906, by J. C. Hoyt and F. F. Henshaw. 1907. 52 pp., 6 pls. (Out of stock.)

WS 197. Water resources of Georgia, by B. M. and M. R. Hall. 1907. 342 pp., 1 pl.

WS 198. Water resources of Kennebec River basin, Maine, by H K. Barrows, with a section on the quality of Kennebec River water, by George C. Whipple. 1907. — pp., 7 pls.

WS 200. Weir experiments, coefficients, and formulas (second edition), by Robert E. Horton. 1907. 195 pp.

WS 215. Geology and water resources of a portion of the Missouri River Valley in northeastern Nebraska, by G. E. Condra. 1908. — pp., — pls.

WS 216. Geology and water resources of the Republican River Valley and adjacent areas, Nebraska, by G. E. Condra. 1907. 71 pp., 13 pls.

SERIES O, UNDERGROUND WATERS.

WS 4. A reconnaissance in southeastern Washington, by I. C. Russell. 1897. 96 pp., 7 pls. (Out of stock.)

WS 6. Underground waters of southwestern Kansas, by Erasmus Haworth. 1897. 65 pp., 12 pls. (Out of stock.)

WS 7. Seepage waters of northern Utah, by Samuel Fortier. 1897. 50 pp., 3 pls. (Out of stock.)

WS 12. Underground waters of southeastern Nebraska, by N. H. Darton. 1898. 56 pp., 21 pls. (Out of stock.)

WS 21. Wells of northern Indiana, by Frank Leverett. 1899. 82 pp., 2 pls. (Out of stock.)

WS 26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett. 1899. 64 pp. (Out of stock.)

WS 30. Water resources of the lower peninsula of Michigan, by A. C. Lane. 1899. 97 pp., 7 pls. (Out of stock.)

WS 31. Lower Michigan mineral waters, by A. C. Lane. 1899. 97 pp., 4 pls. (Out of stock.)

WS 34. Geology and water resources of a portion of southeastern South Dakota, by J. E. Todd. 1900. 34 pp., 19 pls.

WS 53. Geology and water resources of Nez Perces County, Idaho, Pt. I, by I. C. Russell. 1901. 86 pp., 10 pls. (Out of stock.)

WS 54. Geology and water resources of Nez Perces County, Idaho, Pt. II, by I. C. Russell. 1901. 87-141 pp. (Out of stock.)

WS 55. Geology and water resources of a portion of Yakima County, Wash., by G. O. Smith. 1901. 68 pp., 7 pls. (Out of stock.)

WS 57. Preliminary list of deep borings in the United States, Pt. I, by N. H. Darton. 1902. 60 pp. (Out of stock.)

WS 59. Development and application of water in southern California, Pt. I, by J. B. Lippincott. 1902. 95 pp., 11 pls. (Out of stock.)

WS 60. Development and application of water in southern California, Pt. II, by J. B. Lippincott. 1902. 96–140 pp. (Out of stock.)

WS 61. Preliminary list of deep borings in the United States, Pt. II, by N. H. Darton. 1902. 67 pp. (Out of stock.)

WS 67. The motions of underground waters, by C. S. Slichter. 1902. 106 pp., 8 pls. (Out of stock.)

B 199. Geology and water resources of the Snake River Plains of Idaho, by I. C. Russell. 1902. 192 pp., 25 pls.

WS 77. Water resources of Molokai, Hawaiian Islands, by Waldemar Lindgren. 1903. 62 pp., 4 pls.

WS 78. Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon, by I. C. Russell. 1903. 53 pp., 2 pls.

PP 17. Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian, by N. H. Darton. 1903. 69 pp., 43 pls.

WS 90. Geology and water resources of a part of the lower James River Valley, South Dakota, by J. E. Todd and C. M. Hall. 1904. 47 pp., 23 pls.

WS 101. Underground waters of southern Louisiana, by G. D. Harris, with discussions of their uses for water supplies and for rice irrigation, by M. L. Fuller. 1904. 98 pp., 11 pls.

WS 102. Contributions to the hydrology of eastern United States, 1903, by M. L. Fuller. 1904. 522 pp.

WS 104. Underground waters of Gila Valley, Arizona, by W. T. Lee. 1904. 71 pp., 5 pls.

WS 106. Water resources of the Philadelphia district, by Florence Bascom. 1904. 75 pp., 4 pls.

WS 110. Contributions to the hydrology of eastern United States, 1904; M. L. Fuller, geologist in charge. 1904. 211 pp., 5 pls.

PP 32. Geology and underground water resources of the central Great Plains, by N. H. Darton. 1904. 433 pp., 72 pls. (Out of stock.)

WS 111. Preliminary report on underground waters of Washington, by Henry Landes. 1904. 85 pp., 1 pl.

WS 112. Underflow tests in the drainage basin of Los Angeles River, by Homer Hamlin. 1904. 55 pp., 7 pls.

WS 114. Underground waters of eastern United States, by M. L. Fuller, geologist in charge. 1904. 285 pp., 18 pls.

WS 118. Geology and water resources of east-central Washington, by F. C. Calkins. 1905. 96 pp., 4 pls.

B 252. Preliminary report on the geology and water resources of central Oregon, by I. C. Russell. 1905. 138 pp., 24 pls.

WS 120. Bibliographic review and index of papers relating to underground waters, published by the United States Geological Survey, 1879–1904, by M. L. Fuller. 1905. 128 pp.

WS 122. Relation of the law to underground waters, by D. W. Johnson. 1905. 55 pp.

WS 123. Geology and underground water conditions of the Jornada del Muerto, New Mexico, by C. R. Keyes. 1905. 42 pp 9 pls. (Out of stock.)

WS 136. Underground waters of the Salt River Valley, by W. T. Lee. 1905. 194 pp., 24 pls.

B 264. Record of deep-well drilling for 1904, by M. L. Fuller, E. F. Lines, and A. C. Veatch. 1905. 106 pp.

PP 44. Underground water resources of Long Island, New York, by A. C. Veatch and others. 1905. 394 pp., 34 pls.

WS 137. Development of underground waters in the eastern coastal plain region of southern California. by W. C. Mendenhall. 1905. 140 pp., 7 pls.

WS 138. Development of underground waters in the central coastal plain region of southern California, by W. C. Mendenhall. 1905. 162 pp., 5 pls.

WS 139. Development of underground waters in the western coastal plain region of southern California, by W. C. Mendenhall. 1905. 105 pp., 7 pls.

WS 140. Field measurements of the rate of movement of underground waters, by C. S. Slichter. 1905, 122 pp., 15 pls.

WS 141. Observations on the ground waters of Rio Grande Valley, by C. S. Slichter. 1905. 83 pp. 5 pls.

WS 142. Hydrology of San Bernardino Valley, California, by W. C. Mendenhall. 1905. 124 pp., 13 pls.

WS 145. Contributions to the hydrology of eastern United States; M. L. Fuller, geologist in charge, 1905. 220 pp., 6 pls.

WS 148. Geology and water resources of Oklahoma, by C. N. Gould. 1905. 178 pp., 22 pls.

WS 149. Preliminary list of deep borings in the United States, second edition, with additions, by N. H. Darton. 1905. 175 pp.

PP 46. Geology and underground water resources of northern Louisiana and southern Arkansas, by A. C. Veatch. 1906. 422 pp., 51 pls.

WS 153. The underflow in Arkansas Valley in western Kansas, by C. S. Slichter. 1906. 90 pp., 3 pls. (Out of stock.)

WS 154. The geology and water resources of the eastern portion of the Panhandle of Texas, by C. N. Gould. 1906. 64 pp., 15 pls.

WS 155. Fluctuations of the water level in wells, with special reference to Long Island, New York, by A. C. Veatch. 1906. 83 pp., 9 pls.

WS 157. Underground water in the valleys of Utah Lake and Jordan River, Utah, by G. B. Richardson. 1906. 81 pp., 9 pls.

WS 158. Preliminary report on the geology and underground waters of the Roswell artesian area, New Mexico, by C. A. Fisher. 1906. 29 pp., 9 pls.

PP 52. Geology and underground waters of the Arkansas Valley in eastern Colorado, by N. H. Darton. 1906. 90 pp., 28 pls.

WS 159. Summary of underground-water resources of Mississippi, by A. F. Crider and L. C. Johnson. 1906. 86 pp., 6 pls.

PP 53. Geology and water resources of the Bighorn basin, Wyoming, by C. A. Fisher. 1906. 72 pp., 16 pls.

WS 160. Underground-water papers, 1906, by M. L. Fuller. 1906. 104 pp., 1 pl. (Out of stock.)

WS 163. Bibliographic review and index of underground-water literature published in the United States in 1905, by M. L. Fuller, F. G. Clapp, and B. L. Johnson. 1906. 130 pp.

WS 164. Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois, by L. C. Glenn. 1906. 173 pp., 7 pls.

WS 181. Geology and water resources of Owens Valley, California, by W. T. Lee. 1906. 28 pp., 6 pls. (Out of stock.)

WS 182. Flowing wells and municipal water supplies in the southern portion of the southern peninsula of Michigan, by Frank Leverett and others. 1906. 292 pp., 5 pls.

WS 183. Flowing wells and municipal water supplies in the middle and northern portions of the southern peninsula of Michigan, by Frank Leverett and others. 1906. 393 pp., 5 pls.

B 298. Record of deep-well drilling for 1905, by M. L. Fuller and Samuel Sanford. 1906. 299 pp.

WS 184. The underflow of the South Platte Valley, by C. S. Slichter and H. C. Wolff. 1906. 42 pp.

WS 188. Water resources of the Rio Grande Valley in New Mexico and their development, by W. T. Lee. 1906. 59 pp., 10 pls.

WS 190. Underground waters of coastal plain of Texas, by T. U. Taylor. 1907. 73 pp., 3 pls.

WS 191. Geology and water resources of the western portion of the Panhandle of Texas, by C. N. Gould. 1907. 70 pp., 7 pls.

WS 195. Underground waters of Missouri; their geology and utilization, by Edward Shepard. 1907. 224 pp., 6 pls.

WS 199. Underground water in Sanpete and central Sevier valleys, Utah, by G. B. Richardson. 1907. 63 pp., 6 pls.

WS 215. Geology and water resources of a portion of the Missouri River Valley in northeastern Nebraska, by G. E. Condra. 1908. — pp., — pls.

WS 216. Geology and water resources of the Republican River Valley and adjacent areas, Nebraska, by G. E. Condra. 1907. 71 pp., 13 pls.

The following papers also relate to this subject: Underground waters of Arkansas Valley in eastern Colorado, by G. K. Gilbert, in Seventeenth Annual, Pt. II; Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton, in Seventeenth Annual, Pt. II; Water resources of Illinois, by Frank Leverett, in Seventeenth Annual, Pt. II; Water resources of Indiana and Ohio, by Frank Leverett, in Eighteenth Annual, Pt. IV; New developments in well boring and irrigation in eastern South Dakota, by N. H. Darton, in Eighteenth Annual, Pt. IV; Rock waters of Ohio, by Edward Orton, in Nineteenth Annual, Pt. IV; Artesian-well prospects in the Atlantic coastal plain region, by N. H. Darton, Bulletin No. 138.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

AUGUST, 1907.

Water-Supply Paper No. 217

Series { B, Descriptive Geology, 124
0, Underground Waters, 73

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

WATER RESOURCES

OF

BEAVER VALLEY, UTAH

BY

WILLIS T. LEE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1908

CONTENTS.

Page.

Introduction ---------- 5
  Location and extent of the area examined ---------- 5
  Purpose and scope of work ---------- 5
  Cooperation ---------- 6
Geography ---------- 6
  Plateau province ---------- 6
  Basin province ---------- 6
    Deserts ---------- 6
    Isolated basins ---------- 8
    Residual lakes ---------- 8
  Drainage ---------- 9
Geology ---------- 9
  Formations ---------- 9
    Granite ---------- 9
    Paleozoic sediments ---------- 11
    Effusive rocks ---------- 11
    Younger sediments ---------- 12
  Structure ---------- 13
Water supply ---------- 15
  Precipitation ---------- 15
  Surface waters ---------- 17
    Source ---------- 17
    Measurements of flow ---------- 18
    Utilization ---------- 19
  Underground waters ---------- 19
    Springs ---------- 19
      Number and distribution ---------- 19
      Sulphurdale ---------- 19
      McKean ---------- 20
      Minersville ---------- 21
      Dotson ---------- 21
      Thermo ---------- 21
      Other springs ---------- 22
    Seepage waters ---------- 22
      Location ---------- 22
      Volume ---------- 22
    Deep wells ---------- 23
      Classification ---------- 23
      Beaver district ---------- 23
        Barton ---------- 23
        Cemetery ---------- 23
        Mumford ---------- 24
        Nower ---------- 24
        Shepherd ---------- 24
        Wolfenden & Murdock well ---------- 25
        Other Beaver wells ---------- 25
      Greenville district ---------- 25
        Greenville school ---------- 25
        Other Greenville wells ---------- 25
      Adamsville district ---------- 25
        Griffith ---------- 25
        Parkinson ---------- 26
        Other Adamsville wells ---------- 26

Water supply—Continued.
  Underground waters—Continued.
    Deep wells—Continued.

Page.
- Minersville district 26
  - Baker & Walker 26
  - Goodson 27
  - Van Patten 27
  - Other Minersville wells 27
- Milford district 27
  - Milford 27
  - Lewis 28
  - Winberg 28
  - Railroad 29
  - Milwaukee Leasing Company 29
  - Mining and Smelting Company 30
  - Beaver Bottoms 30
- Railroad wells outside of Beaver Valley 30
  - Beryl 31
  - Lund 31
  - Thermo 32
  - Neels 32
  - Oasis 33
  - Lynn 34
- Statistics of deep wells 34

Shallow wells 37
- Tabulated data 37
- Water-bearing material 40
- Changes in water level 41

Chemical character of waters 42
- Methods of determination 42
- Streams 42
- Springs 43
- Deep wells 46
- Shallow wells 46
- Beaver wells 47
- Sanitary analyses 49
- Other exact analyses 49

Possibilities of development 51
- Surface waters 51
- Underground waters 51
  - Drainage 51
  - Pumping plants 52
  - Artesian conditions 54

Index 55

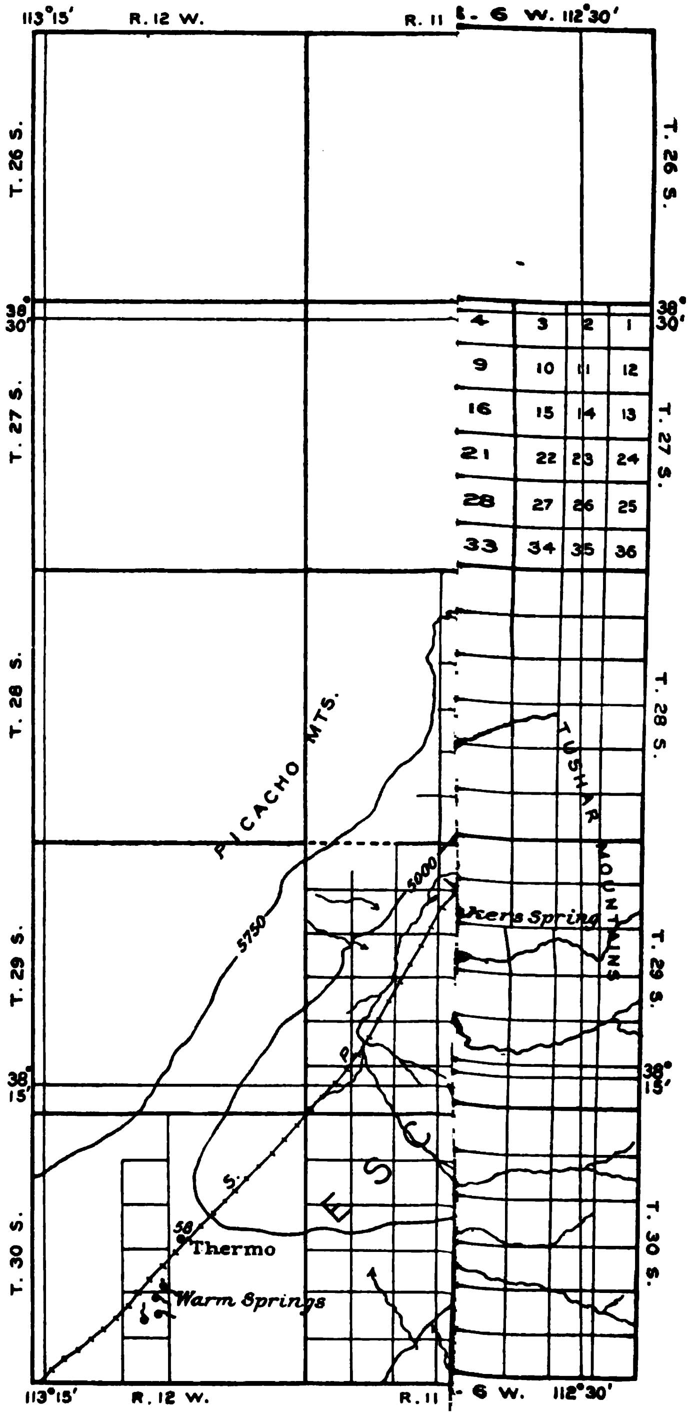
ILLUSTRATIONS.

Page.

PLATE I. Map of Beaver Valley 5
FIG. 1. Map of Utah showing location of Beaver Valley with an outline of Lake Bonneville 7
2. East-west section across Beaver Basin 14
3. Map of Beaver 48

U.S. GEOLOGICAL SURVEY

.217 PL. I



SKETCH MAP OF BE

WATER RESOURCES OF BEAVER VALLEY, UTAH.

By Willis T. Lee.

INTRODUCTION.

Location and extent of area examined.—Beaver Valley is located in Beaver County, in southwestern Utah, about 175 miles south of Salt Lake. It lies between the Tushar Mountains on the east and the Beaver Mountains on the west. The principal town of the valley is Beaver, which is most conveniently reached from Milford, a station on the San Pedro, Los Angeles and Salt Lake Railroad. The valley, together with its neighboring highlands, occupies the eastern third of Beaver County, an area of about 1,200 square miles. A large part of this area, however, is rocky upland and unproductive desert, the tillable land comprising a comparatively small area in the immediate vicinity of the streams.

Purpose and scope of work.—The purpose of this paper is to present information concerning the waters of Beaver Valley and to point out ways and means of increasing their usefulness.

The presence of a large amount of water in Beaver Valley results from local topograhic conditions, the water being supplied by precipitation in the highland to the east. Its conservation and distribution result from geologic conditions, the water being held in loose gravel and sand, which are more or less confined between ridges of consolidated rocks. The rock basins were formed partly by erosion and partly by faulting and surface deformation. In order to accomplish the purpose in view it is therefore necessary to describe the geographic and geologic conditions in Beaver Valley and neighboring regions.

The investigation included the determination of the flow of streams and springs, of the manner of occurrence and quantity of the underground waters as shown by the geologic and geographic conditions of the region and by the distribution of springs and wells, and of the chemical character of the waters with reference to their adaptability to domestic use and to irrigation. The chemical data were obtained (*a*) by field assays, which are approximately correct and probably of sufficient accuracy to be of value in comparing the various waters; (*b*) by more exact analyses, some of which were made in the laboratory of the United States Geological Survey by W. M. Barr, and others by Herman Harms, State chemist of Utah, for the San Pedro, Los Angeles and Salt Lake Railroad; and (*c*) by sanitary analyses, made also by Herman Harms.

Cooperation.—The work was done during the summer of 1906, the United States Geological Survey cooperating with the State of Utah through Caleb Tanner, State engineer, and with the county of Beaver through the supervisors of the county. In collecting the information the writer was assisted by J. F. Hoyt, of Nephi, Utah.

GEOGRAPHY.

Southwestern Utah is divided into two general provinces—the plateau province and the basin province. These are separated sharply by a succession of high cliffs extending in a northeasterly direction from St. George through Beaver and northward. At the foot of these cliffs are located the principal towns of the southwestern part of the State—for example, St. George, Toquerville, Kanarraville, Cedar City, Parowan, Beaver, and Fillmore. To the east of the cliffs lie the High Plateaus of Utah, well known through the writings of Dutton, Powell, Gilbert, and others; and to the west of them lie the barren deserts of the Great Basin.

PLATEAU PROVINCE.

The High Plateaus lie at an elevation several thousand feet above the Great Basin, and isolated mountains of volcanic origin rise to altitudes considerably greater than that of the general surface of the plateaus, the highest in the vicinity of Beaver being Delano Peak, which has an altitude of 12,240 feet. These plateaus and mountains are of the greatest importance in considering the water supply, since owing to their altitude the rainfall is greater there than in the basin region to the west. The streams which yield the water supply of southwestern Utah all rise in the highlands of the plateaus.

BASIN PROVINCE.

DESERTS.

The Great Basin consists of broad sandy deserts, from the surface of which rise more or less isolated groups of rock mountains. The Great Basin has been described by Gilbert[a] and others, who show that the lowest parts were formerly occupied by a lake known as Lake Bonneville, an outline of which is shown on the accompanying map (fig. 1). Sands, gravels, and clays were deposited in this lake to a great though unknown depth, filling the low places generally and transforming into nearly level plains large areas which may pre-

---

[a] Gilbert, G. K., Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890.

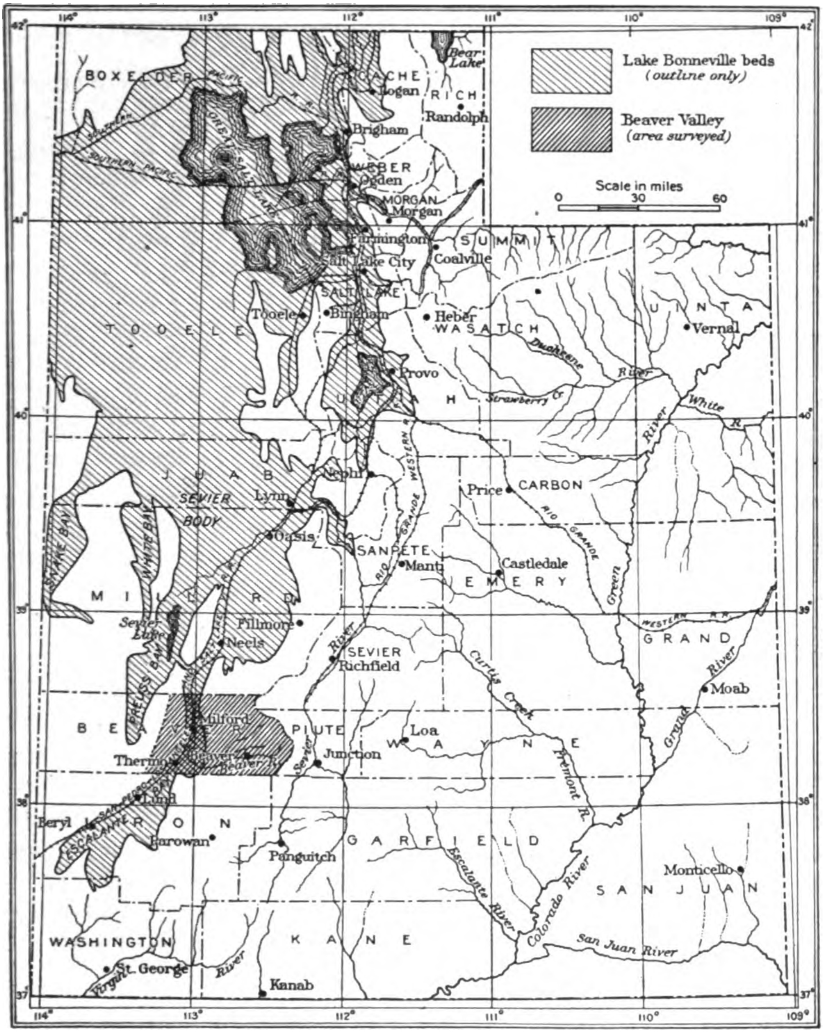


FIG. 1.—**Map of Utah, showing location of Beaver Valley and outline of Lake Bonneville. (After G. K. Gilbert, Mon. U. S. Geol. Survey, vol. 1, 1890.)**

viously have had very uneven surfaces. The Escalante Desert, a part of which lies within the region described in this paper, represents the southernmost extension of Lake Bonneville, called by Gilbert Escalante Bay. A comparatively narrow strait, here about 6 miles wide, connected Escalante Bay with the main body of Lake Bonneville to the north. The bed of the old lake is now represented by the level bottom lands of the desert. Rock mountains rise abruptly from the plains, and material from the mountains, borne out by the streams and deposited as alluvial slopes and cones, from the gentle outwash slopes, characteristic of the desert region.

ISOLATED BASINS.

Between the High Plateaus and the Escalante Desert there are several comparatively small basins, some at an elevation but little greater than that of the Escalante Desert, as Rush Lake Valley; others several hundred feet higher, as Parowan Valley, which is separated from the main desert by highlands except where they are cut by a narrow canyon through which the valley was formerly drained, but which is now dry; and Beaver Basin, 1,000 feet or more above the floor of the Escalante Desert, with which it is connected by a canyon at Minersville, carved by Beaver River through the Mineral Mountains.

These basins, as described in detail in the case of Beaver Basin, are partly filled with sediments similar to those of Lake Bonneville, from which it might be inferred that they were formerly small embayments of the lake that were later elevated to their present position by crustal movements. This inference finds some confirmation in recent earthquake disturbances that are known to have occurred in this region, and in the fact that the basins lie in a zone of profound faulting, which has been subject to the differential movements that have resulted in the great differences of elevation between the High Plateaus and the Great Basin. It seems more probable, however, that these basins formerly contained isolated lakes that were tributary to Lake Bonneville and lay at altitudes somewhere greater than the main lake, much as Utah Lake is tributary to Great Salt Lake at the present time. Beaver Basin, the only one of these small basins within the area described, will be referred to frequently, and for convenience the deposits filling it may be called the Beaver Lake beds and the body of water in which they were laid down may be called Beaver Lake.

RESIDUAL LAKES.

In certain places where the water supply is sufficient the lower portions of the old lake bed still contain small salt lakes, such as Sevier Lake, Little Salt Lake in Parowan Valley, and Blue Lake near Deseret. In other places water gathers in the depressions during wet weather and forms mud flats, one of which, known as Beaver Bottoms, is within the area here described. Many parts of the Escalante Desert are so nearly level that rain water accumulates at the surface and stands practically motionless until absorbed into the ground, and during wet weather much of the desert becomes an impassable bog.

DRAINAGE.

The drainage with which this paper is concerned is entirely that of Beaver River and its tributaries. All the permanent streams entering the valley rise in the Tushar Mountains to the east, and the trunk stream of the system supplies the greater part of the water, since it has its origin in the highest part of the range among such lofty peaks as Delano (altitude 12,240 feet), Baldy (altitude 11,730 feet), and Belknap (altitude 12,200 feet). The main tributaries are South Creek, Burch Creek, North Creek, Indian Creek, and Wildcat Creek, all of which rise in the Tushar Mountains and join the river within Beaver Basin. There are no other tributaries having perennial flows, and after leaving Beaver Basin the river rapidly decreases in volume until at Milford it also becomes intermittent. Still farther to the north the trunk channel subdivides into the distributary channels of Beaver Bottoms. The river is nominally a part of the Sevier Lake drainage, but according to report it is only occasionally that a flood has sufficient volume to find its way into the lake.

The greater part of the water passing Minersville finds its way quickly into the sands and gravels of the Lake Bonneville beds. The sediments swept from the canyon are deposited upon the plain to the west of Minersville, forming a delta fan. The fan is so nearly flat and its surface is so regular, as compared with the outwash slopes of the mountains near by, that the delta character is inconspicuous. Its presence is made clear, however, by the distribution of the streams. Beaver River at the present time follows the northern edge of the delta, but the water diverted from the river at Minersville for the irrigation of the fields southwest of the town finds its way westward near the southern edge of the delta, gradually turning to the north and finally entering the river again about 2 miles south of Milford. The low ground obviously marks an abandoned course of Beaver River, and it would apparently require little effort, perhaps nothing more than a clogging of the present channel with débris during some flood, to turn it back into the old course.

GEOLOGY.

FORMATIONS.

GRANITE.

The oldest rocks exposed at the surface in the Beaver region are supposed to be the granites of the Mineral Mountains. They underlie and are apparently older than the Paleozoic sediments. They have been subjected to comparatively recent movements, as is made evident by the occurrence of faults and zones of crushing and shearing and by the presence of hot springs in the shear zones. It is possible, however, that the granites, instead of being pre-Paleozoic in age, are due to comparatively recent intrusions. The region is one in which great crustal disturbances have taken place, as is indicated by the faulted and tilted sediments described on page 14 and by the great masses of extrusive rock found in the Tushar Mountains and elsewhere. The volcanic disturbances have occurred repeatedly, as shown by the alternation of early Tertiary lavas and sediments and the occurrence of basalt included within the Quaternary gravels and resting upon them in the form of sheets and volcanic cones.

Section of rocks exposed in Beaver Canyon 4 miles east of Minersville.

		Feet.
1.	Basalt, several hundred feet.	
2.	Rhyolitic flows, tuffs and breccia, many hundred feet.	
3.	Andesitic flows, tuffs and breccia, several hundred feet.	
4.	Uncemented gravel and bowlders of limestone, quartzite, and andesite	250
5.	Coarse consolidated conglomerate consisting of limestone, quartzite, and various crystalline rocks, the bowlders having a maximum diameter of 5 feet	90
	Unconformity.	
6.	Red shale	60
7.	Earthy-gray limestone	15
8.	Red shale	10
9.	Gray limestone	10
10.	Red shale and ripple-marked sandstones	40
11.	Blue limestone	10
12.	Red shale and ripple-marked sandstones	120
13.	Limestone containing *Aviculipecten weberensis*, *Aviculipecten* aff. *occidentalis*, *Myalina* aff. *perattenuata*, *Bakewellia* n. sp., *Pleurophorus* sp., *Schizodus* sp	15
14.	Shale	40
15.	Limestone containing same fossils as No. 13	15
16.	Buff shale with a subordinate amount of limestone	95
17.	Shale and limestone containing *Aviculipecten* n. sp., *Pleurotomaria?* sp., *Bakewellia* n. sp., *Naticopsis* sp., *Xenodiscus?* sp., undetermined ammonoids	100
18.	Red shale	35
19.	Yellowish brown shales alternating with ripple-marked sandstones	40
20.	Quartzitic basal conglomerate	10
	Unconformity.	
21.	Cherty limestone containing *Zaphrentis?* sp., *Fistulipora* sp., *Septopora* sp., *Productus* aff. *subhorridus*, *Meekella?* sp., *Spirifer* aff. *cameratus*, *Squamularia* aff. *perplexa*, *Spiriferina* aff. *kentuckyensis*, *Spiriferina* sp., *Composita* aff. *subtilita*, *Hustedia* aff. *meekana*, *Pugnax* aff. *osagensis*	450
22.	Yellowish quartzite	200
23.	Cherty limestone containing *Squamularia?* sp. and *Hustedia* aff. *meekana*	500

Base not exposed where section was measured.

PALEOZOIC SEDIMENTS.

A thick series of massive limestones overlies the granite and is well exposed in the Mineral Mountains north of Minersville. These limestones are overlain in turn by red sandstones, shale, and volcanic products, as shown in the section on the preceding page.

The massive cherty limestone at the base of the section is referred with little doubt to the Aubrey. The fossils were examined by George H. Girty, of the United States Geological Survey, who states that they probably belong in the Aubrey fauna, although many of the most characteristic forms of that fauna are wanting. The stratigraphic position and general field relations of the limestone show that it is probably the same as the typical Aubrey limestone of the Grand Canyon region farther to the south.

The red sediments overlying the cherty limestone yielded a number of well-preserved fossils which also have been examined by Doctor Girty, who states that the fauna is the same as that of the Permian beds of Walcott's[a] Grand Canyon section and of the "Permo-Carboniferous" of the Wasatch Mountains.

In Colob Plateau, about 50 miles south of Beaver, a thickness of more than 8,000 feet of strata was measured between the base of the Permian and the top of the Benton. Of this great thickness only 565 feet of the base of the Permian remain in Beaver Canyon, the upper beds having been eroded away. The red beds are overlain by a coarse conglomerate, presumably equivalent in age to the Eocene conglomerates of the plateaus, and these are covered in turn by extensive masses of volcanic rock.

EFFUSIVE ROCKS.

The oldest of the lavas covering the red beds and the overlying conglomerate are dark-colored andesites. These are most conveniently seen in the Beaver region in the canyon east of Minersville. They consist of flow sheets, tuffs, and volcanic breccias and occur also as bowlders in the underlying conglomerate.

Above the andesites are extensive masses of light-pink to white rhyolite. These are especially large in the Tushar Mountains, where they occur as flow sheets, tuffs, and breccias, constituting a large part of the range. The rhyolites are best known locally as the soft pink rock found near the mouth of Beaver Canyon and elsewhere, that is used for building purposes. It is a fine-grained, consolidated rhyolitic tuff which, on account of its softness, is easily quarried and dressed, but which is resistant enough to make a good building stone. In many places masses of this tuff are not well consolidated and resemble beds of light-colored sand and clay.

---

[a] Walcott, C. D., The Permian and other Paleozoic groups of the Kanab Valley, Arizona: Am. Jour. Sci., 3d ser., vol. 20, 1880, pp. 221, 225.

After some, at least, and probably after all of the rhyolites of this region had been extruded they were extensively eroded, as shown by the occurrence of beds of conglomerate made up largely of pebbles and bowlders of rhyolite. These conglomerates of rhyolite occur in Beaver Canyon at Minersville, in Bakers Canyon, 5 miles east of Beaver, and elsewhere. At Minersville they are well stratified, but consist mainly of angular fragments of rhyolite. In Bakers Canyon they are several hundred feet thick and made up of well-rounded pebbles and bowlders of many kinds of rock, the largest bowlders consisting of rhyolite.

Basalt overlies the rhyolitic rocks and rests in some places upon the conglomerates and in others upon the tuffs and breccias. The basalt is the black rock used to a considerable extent as a building stone in Beaver Valley. It occurs in sheets near the mouth of Beaver Canyon, in the canyon east of Minersville, in Black Mountain north of Beaver, and elsewhere. It also forms the volcanic cones, one of which is located 13 miles north of Beaver and another 20 miles north of Beaver near the Cove Creek sulphur beds.

YOUNGER SEDIMENTS.

The sediments to the west and north of Minersville, the only part of the Escalante Desert within the region here described, constitute a part of the Lake Bonneville beds. The Escalante Desert, an outline of which is shown in fig. 1 (p. 7), has a general elevation greater than that of the main part of the old lake basin and was included in the lake as Escalante Bay, at least during the closing stages of sedimentation, only during the maximum extension of the lake, as shown in Gilbert's map, Pl. XIII of the Bonneville monograph. For this reason the shore lines, so conspicuous along the mountain sides in the vicinity of Salt Lake, are practically absent in the vicinity of Milford, the altitude of the more conspicuous ones near Salt Lake being less than that of the surface of the Escalante Desert. For the same reason the wave-built terraces are not so conspicuous as they are in other places, although they occur as low sand and gravel benches at a greater or less distance from the hills and in many places near the center of the desert.

The lack of vertical exposures of any considerable thickness renders impossible a detailed description of the sediments except those near the surface. Such well records as are available, however, show that the beds consist principally of clay and fine sand with a subordinate amount of gravel. The wells at Thermo and Milford, the drillers' records of which are given on pages 29, 32, are within the area described and give the most exact information available regarding the character of the Lake Bonneville beds in Beaver County.

The maximum thickness of these beds is not known. The only well that penetrates through them is located at Neels, and shows a thickness of sediment of nearly 2,000 feet. It is possible that the lower parts of these sediments may be of pre-Bonneville age, but there is no indication in the driller's record (given on p. 33) that they do not all belong to the Lake Bonneville beds. It is noteworthy also that Neels is located in a narrow strait of Lake Bonneville, and it is altogether probable that in the broader parts of the basin the sediments may be much thicker.

The sediments of Beaver Basin consist of unconsolidated clay, sand, and gravel in alternating layers, as shown in detail in the well records (pp. 23–26). Their character and distribution, as well as their similarity to the Lake Bonneville beds, seems to warrant the inference that they are lake deposits. A thickness of several hundred feet is exposed in the mesas near Beaver, and an additional thickness of nearly 500 feet is shown by the wells, but the total depth of the sediments within Beaver Basin is not known.

The Beaver Lake beds are similar to the Lake Bonneville beds in general character, degree of consolidation, and association with flows of basalt. For these reasons the Beaver Lake beds are believed to be of the same age as the Lake Bonneville beds, although they lie at an elevation 1,000 feet or more above the Lake Bonneville sediments of the Escalante Desert. This difference in elevation, as previously suggested, may be due to recent elevation, but is more probably to be accounted for as the result of deposition in a lake tributary to Lake Bonneville and lying at a greater elevation.

STRUCTURE.

The geologic structure in the Beaver region is somewhat difficult to make out owing to the occurrence of the great quantities of eruptive rock and to the recent accumulation of sediments—the Beaver Lake and the Lake Bonneville beds—which cover or obscure the faults. Farther south, however, the older sedimentary rocks are better exposed and their structural relations are plainly discernible.

Along the western border of the High Plateaus of Utah, between Beaver and St. George, several basins have been formed apparently by faulting and the displacement of large crust blocks. Rush Lake Valley (or Cedar Valley, as it is sometimes called) and Parowan Valley are perhaps the most conspicuous of these basins. The strata of the plateaus to the east lie essentially horizontal, except where faulted blocks have been displaced, but the same formations to the west of the cliffs that form the western margin of the plateaus dip eastward beneath the basins. In order to avoid possible misunderstanding, it should be noted in this connection that the hills west of Parowan, mapped by Dutton[a] as trachyte and rhyolite, were found to consist mainly of sandstones and conglomerates similar to those of the plateau east of Parowan, which, as stated by the same author, are sediments of Cretaceous and Tertiary age.

The fault at which the great displacements occurred to form these basins is known as the Hurricane fault, and the northward extension of the Hurricane ledge of the plateau region of southern Utah forms the western margin of the plateaus in Cedar and Parowan valleys. The Hurricane fault, or the zone of faulting in which it occurs, is traceable from the Grand Canyon northward to the lava fields between Parowan and Beaver valleys, where it could not be followed through the effusive rocks. But a number of facts indicate that Beaver Basin, like Parowan Valley, was formed by faulting and crust-block tilting. Among these facts are the following:

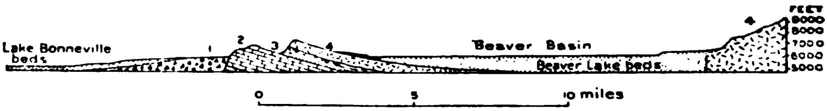


FIG. 2.—East-west section through Beaver, showing structure of Beaver Basin and relation of Beaver Lake beds to Lake Bonneville beds. 1, Volcanic breccia (Tertiary); 2, Aubrey limestone (Carboniferous); 3, red sandstone and shale (Permian); 4, andesite and rhyolite.

The sedimentary formations of the plateau region occur in the Tushar Mountains beneath the igneous rocks. They are exposed, according to Dutton,[b] in the eastern flanks of these mountains and are said to occur also in the western flanks in small detached blocks, one of which, at least, is limestone from which lime is obtained for local uses. The writer did not see these sediments, but in the Mineral Mountains the Paleozoic formations, a section of which is given on page 10, were observed dipping steeply to the east and passing underneath lavas identical in kind and constitution with those of Tushar Mountains. These in turn are finally buried by the sands and gravels of the Beaver Lake beds. The sedimentary rocks terminate abruptly at the west against the breccias composed of volcanic rock which have been described as younger than the rhyolites. This is evidently due to the presence of a fault along the western face of the Mineral Mountains. The probable structural relations are shown in the sketch section, fig. 2.

---

[a] Dutton, C. E., Tertiary history of the Grand Canyon district: Mon. U. S. Geol. Survey, vol. 2, 1882, atlas sheet No. 21.

[b] Dutton, C. E., Geology of the High Plateaus of Utah, 1880, atlas sheet No. 6, sec. No. 4.

Further evidence that Beaver Basin is in a zone of faulting is found in the prevalence of earthquakes. A number of severe shocks have occurred within recent years, the zone of greatest disturbance following in general the fault zone at the edge of the plateau. In this same zone also occur the volcanic cones north of Beaver, the beds of sulphur at Sulphurdale that have been described by the writer[a] as being still in process of accumulation, and numerous large springs, some of which yield waters that are hot and highly mineralized.

WATER SUPPLY.

PRECIPITATION.

Few rainfall records sufficiently complete to be of great use are available from southern Utah. Those that are close enough to the region here described to indicate the precipitation in this region are given below. From these records, representing 11 stations, it appears that the average rainfall, computed from the 78 complete yearly records only, is 10.81 inches.

TABLE 1.—*Records of precipitation at stations in southwestern Utah.*

BEAVER. (ALTITUDE, 5,970 FEET.)

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1889	------	------	------	------	1.20	0.86	0.38	1.93	0.40	1.62	0.14	3.79	------
1890	1.08	0.67	0.53	0.60	.12	Tr.	.51	.44	1.22	.17	.27	.50	6.06
1891	.41	1.17	.33	1.09	.61	1.14	1.36	1.25	1.24	Tr.	.00	1.50	10.10
1892	.81	------	1.17	1.12	------	.10	1.20	------	------	------	------	1.75	------
1893	.45	1.38	1.45	2.04	.50	.00	------	------	------	------	------	------	------
1904[a]	------	------	------	------	------	------	1.20	1.13	.38	.67	.00	.40	------
1905	.06	2.35	1.34	1.13	2.49	.00	.47	.95	2.07	.30	.85	.20	12.21
1906	1.10	1.09	3.50	1.62	1.86	------	------	2.04	1.27	------	.85	------	------

[a] Ten years' record wanting.

BLACKROCK. (ALTITUDE, 4,872 FEET.)

1901	0.40	1.43	0.34	1.29	0.78	0.94	0.15	1.02	0.00	0.56	Tr.	0.70	7.61
1902	.26	.20	1.15	.16	.23	Tr.	.40	.19	.84	.53	1.97	.45	6.38
1903	1.11	1.30	2.00	2.59	1.72	.83	.41	1.75	.92	.95	.10	.18	13.36
1904	4.10	1.00	.93	.26	1.64	.04	.05	.56	.30	.65	.00	.55	6.39
1905	.48	2.26	1.74	1.28	1.52	Tr.	.65	.75	2.57	.88	------	------	------
1906	1.59	------	------	3.31	.91	.12	------	1.12	2.33	.03	2.11	.97	------

DESERET. (ALTITUDE, 4,541 FEET.)

1891	------	------	------	------	------	------	------	0.64	0.62	0.05	0.00	0.21	------
1892	0.53	1.30	1.84	0.71	1.81	0.14	0.42	.58	.06	1.12	.10	.86	9.47
1893	.54	.61	1.85	1.40	.67	.00	.21	.91	.46	.05	.14	.82	7.66
1894	.35	1.35	.53	.64	.43	1.29	.25	.23	1.67	.39	.00	.88	8.01
1895	.40	.53	.63	.84	------	Tr.	Tr.	Tr.	.80	.45	.84	.38	------
1896	.32	------	.29	.47	------	------	------	------	------	------	------	------	------
1899	------	------	------	------	------	------	------	------	Tr.	1.23	.34	.80	------
1900	.36	.05	Tr.	2.85	.10	.03	Tr.	Tr.	1.12	.39	.48	.00	5.38
1901	.10	1.67	.80	1.02	1.90	.62	.03	1.54	.08	.50	.04	.76	9.01
1902	.48	.30	.82	.36	.32	Tr.	.06	.04	.40	.20	1.65	.20	4.85
1903	.94	1.30	.40	.90	1.53	.40	Tr.	.08	.67	.72	Tr.	.05	6.99
1904	.15	.97	1.55	.13	2.13	.60	Tr.	.20	.32	.32	.00	.77	7.14
1905	.42	1.25	1.06	1.36	1.35	.00	.00	1.15	1.79	Tr.	1.25	.13	9.76
1906	.31	.41	2.10	1.63	1.06	.19	------	.63	.95	Tr.	1.38	.94	11.77

---

[a] Bull. U. S. Geol. Survey No. 315, 1907, pp. 485–489.

Table 1.—*Records of precipitation at stations in southwestern Utah*—Continued.

FILLMORE. (ALTITUDE, 5,100 FEET.)

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1892	------	------	------	2.11	2.08	0.82	0.29	0.47	0.06	1.07	0.53	1.20	------
1893	0.81	1.51	2.89	2.09	1.53	.00	.48	1.71	1.21	.46	1.11	1.79	15.59
1894	.70	.56	1.04	2.43	.64	2.04	.34	1.19	1.94	.41	.31	1.77	13.37
1895	1.93	2.15	2.06	1.23	1.51	.80	.56	.97	1.66	.98	1.46	1.10	16.36
1896	.75	.16	.94	1.47	1.06	.01	2.36	1.69	.85	.37	1.17	.33	11.16
1897	2.15	2.17	2.89	1.26	.08	.26	.19	.31	1.50	3.59	1.15	1.55	17.04
1898	.15	1.20	3.07	.59	4.44	.96	.99	.06	Tr.	.60	1.27	.76	14.59
1899	.50	1.40	5.00	1.45	.85	.96	.01	.28	.00	1.94	1.06	1.03	14.48
1900	1.25	.45	.15	3.15	.35	.60	Tr.	.14	1.58	.93	.66	.03	9.32
1901	.35	2.00	1.54	2.35	1.92	.57	.41	.90	.00	.72	.15	1.97	12.88
1902	1.03	1.03	2.59	.36	.90	.09	.49	.16	1.51	.58	2.70	.46	11.90
1903	1.44	1.26	1.19	2.66	2.27	.04	.27	.38	1.00	1.06	.00	.40	11.97
1904	1.89	1.90	2.16	.26	2.81	.25	.07	1.13	.10	.62	.00	.95	12.14
1905	.90	2.48	2.66	1.53	2.45	Tr.	.58	.62	2.81	.51	1.13	.54	16.16
1906	.72	1.16	3.88	4.38	2.18	.40	1.27	1.20	2.38	.15	2.93	.63	21.28

FRISCO. (Altitude, 6,250 feet.)

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1897	------	0.30	0.44	Tr.	0.20	0.11	0.16	0.19	1.21	1.50	0.45	1.00	------
1898	0.42	.10	.12	0.41	2.59	.11	.97	1.46	.00	.31	.15	.24	6.88
1899	.10	.65	2.56	1.01	.08	.36	.81	.18	Tr.	.51	.28	Tr.	6.54
1900	.11	.04	.03	1.73	------	.04	Tr.	.05	1.41	.77	.55	.05	------
1901	.35	2.36	.28	.86	1.42	.97	1.76	.64	Tr.	.68	Tr.	.75	10.07
1902	.95	.02	.72	.10	Tr.	Tr.	.74	.82	.47	.15	1.22	.39	5.58
1903	.75	1.66	.68	1.49	1.88	.66	.72	1.12	.82	.85	.02	.07	10.72
1904	.50	.64	.97	.10	2.49	.11	.86	.83	.45	.41	.00	.22	7.58
1905	.66	1.44	1.71	.58	1.44	.02	.58	1.04	2.32	.89	.83	.30	11.81
1906	.10	.56	------	------	------	------	------	------	------	------	.98	.95	------

GARRISON.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1903	0.66	0.60	0.20	0.38	1.16	0.54	0.05	0.55	0.38	0.23	Tr.	Tr.	4.75
1904	.07	1.49	.62	.06	.97	.41	.98	.95	.55	.94	0.00	0.22	7.21
1905	.37	1.30	.30	.99	1.83	Tr.	.10	.83	.85	.00	2.14	.11	8.82
1906	------	Tr.	2.47	1.58	.77	.06	.33	------	.50	.10	1.98	.58	------

MINERSVILLE.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1897	------	1.75	2.40	0.16	0.28	0.03	0.91	0.49	2.07	1.57	0.49	1.52	------
1898	1.49	.57	2.08	.25	2.35	.46	.51	.94	.11	.08	.66	.29	9.79
1899	.57	.38	2.40	.71	.65	.17	1.20	.63	Tr.	1.38	.52	.63	9.24
1900	.34	.20	.34	2.32	.32	.13	.04	------	------	.62	1.33	.05	------
1901	.45	2.21	.51	.87	1.05	.55	.86	1.60	.02	.70	.16	.72	9.70
1902	.91	.29	1.22	.12	.07	------	.41	.48	.97	.10	2.70	------	------
1903	.14	.94	1.10	------	------	------	------	------	------	------	------	.00	------
1904	.70	1.70	------	------	------	------	------	------	------	Tr.	.00	.80	------

MODENA. (ALTITUDE, 5,479 FEET.)

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1902	0.33	0.32	0.54	0.13	0.19	0.02	Tr.	1.58	0.76	0.04	0.89	0.29	5.09
1903	.12	.85	.74	.61	.55	.13	0.14	.92	1.48	1.39	.00	.00	6.93
1904	.20	1.01	.98	.02	1.55	.11	.69	1.52	2.02	.50	.00	.23	9.83
1905	.86	1.79	2.00	1.05	.72	Tr.	.81	1.71	1.26	1.00	.90	.20	12.30
1906	.67	.47	3.22	2.91	1.31	.00	2.30	3.40	.91	.34	1.40	2.13	19.06

PAROWAN. (ALTITUDE, 5,970 FEET.)

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1890	------	------	------	------	------	------	------	------	0.93	0.59	0.43	0.34	------
1891	1.46	2.07	2.57	1.57	1.14	0.20	1.24	0.76	2.10	.00	.00	1.13	14.24
1892	.47	1.03	1.79	2.08	.83	.04	.66	1.24	.00	2.32	.20	.39	11.00
1893	.84	1.03	1.23	1.42	1.34	.00	2.08	1.65	1.11	Tr.	1.38	.72	12.80
1894	1.65	.85	2.65	1.27	.55	.57	.78	1.40	.72	.65	Tr.	1.88	12.97
1895	1.94	2.82	1.93	.47	.87	.06	.70	.23	.29	.58	1.28	.90	12.07
1896	.16	.48	.71	.83	.93	.08	1.69	3.00	.47	.36	.30	.16	9.17
1897	1.50	3.45	3.76	.95	.51	.02	.79	1.56	1.84	2.48	.73	.88	18.47
1898	1.90	1.20	1.66	.64	3.35	.24	1.19	1.46	.25	.30	.72	.82	13.82
1899	.12	1.10	2.18	1.20	1.19	.82	.72	.82	.08	.78	.31	1.60	10.92

TABLE 1.—*Records of precipitation at stations in southwestern Utah*—Continued.

PAROWAN. (ALTITUDE, 5,970 FEET)—Continued.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1900	.51	.23	.18	2.64	.61	.13	.11	.84	.82	.56	.34	.07	7.04
1901	.68	1.84	.85	1.61	.88	.50	.04	3.35	.04	.32	.03	.96	11.05
1902	1.18	.31	1.83	.21	.18	.06	.49	.76	.50	.61	1.86	1.03	9.02
1903	1.10	.77	1.94	1.66	1.10	.49	.41	1.46	1.00	2.03	Tr.	.53	11.89
1904	.43	1.46	2.11	1.27	2.07	.07	.98	1.23	.17	.74	Tr.	.79	11.32
1905	.52	1.54	2.29	.66	1.99	Tr.	.75	.37	3.80	.12	1.11	.32	13.47
1906	1.4	.98	3.99	1.95	.62	Tr.	1.71	3.10	3.49	.41	2.09	1.18	20.87

PINTO. (ALTITUDE, 5,907 FEET.)

1897	------	3.05	4.11	0.78	0.52	0.65	0.90	0.89	2.17	3.76	0.40	1.16	------
1898	1.28	.68	1.33	.39	2.30	.25	.07	.60	.00	.00	.11	.11	7.12
1899	.25	.35	2.17	.40	.58	.77	.05	1.06	.00	1.75	.67	.49	8.54
1900	.38	.27	.34	2.31	.65	.25	.18	.08	1.32	.77	3.16	.05	9.71
1901	1.72	2.74	.23	.85	.85	.45	.80	5.07	.00	1.43	.39	.57	15.10
1902	.61	.95	2.66	.25	.19	Tr.	.01	1.71	.20	.98	3.09	70	11.30
1903	.98	1.06	1.57	1.30	.80	.17	Tr.	1.74	1.37	1.75	.00	.21	10.40
1904	.80	1.91	1.72	.44	1.90	------	3.25	1.97	.99	.91	.00	.17	------
1905	.64	1.88	2.28	1.48	2.09	.00	1.41	1.83	4.82	.77	1.67	.08	18.95
1906	2.72	1.52	6.45	2.15	.98	.17	1.64	2.82	1.82	.10	2.43	2.85	25.60

PIOCHE, NEV.

1877	------	------	------	------	------	------	------	0.18	0.16	0.48	0.00	0.95	------
1878	0.46	1.67	0.73	1.31	1.27	0.04	0.29	.97	.22	.35	.63	.42	8.36
1879	1.12	.17	.12	1.68	.03	.40	.17	.46	.00	.66	.38	1.75	6.94
1880	.21	.36	.12	.46	.01	.08	.18	.47	.18	.52	.29	1.84	4.67
1881	.47	.29	.47	1.08	.21	.08	.23	1.73	.00	.56	.10	.08	5.25
1882	.38	.55	.30	.98	.29	3.23	.21	.95	.03	.60	.71	.08	8.31
1883	.20	.28	.50	1.15	.33	------	------	------	------	------	------	------	------

SURFACE WATERS.

SOURCE.

The waters of Beaver Valley are derived almost entirely from the Tushar Mountains and result directly from the heavy precipitation about the lofty peaks, from which they enter the valley as streams. The rate of run-off from the mountains is regulated by the porous condition of the rocks and by the accumulations of snow. The elevation is such that the snow which falls during the winter melts gradually and feeds the streams during the spring and early part of the summer. The loose volcanic tuffs and breccias absorb large quantities of the water derived both from the rainfall and from the melting snows, and these waters are held back because of their slow movement through the rocks and finally issue in the form of springs having a comparatively regular flow. This conservation of the waters is of the greatest importance to the agricultural regions dependent upon the run-off and will be greatly enhanced by the forest reserve which has recently been established in the Tushar Mountains.

MEASUREMENTS OF FLOW.

Little is known thus far of the actual quantity of water entering Beaver Valley. The settlement of the valley has taken place gradually, the first settlers appropriating all the water they wanted and the later ones taking what they could get. All the summer flow has long since been appropriated, although much of it is misused.

There is imperfect adjudication of rights and little knowledge of the actual volume appropriated in any particular case. The canals and ditches are poorly constructed. In some of them the water flows too rapidly and actively erodes the beds, thus increasing the volume carried. Others have not fall enough and the water fills them with silt, thus decreasing the volume carried. The amount of irrigated land is approximately as follows:

From Beaver River, 9,500 acres, of which 4,036 acres are supplied only during high water.

From South Creek, about 200 acres.
From North Creek, about 1,297 acres.
From Indian Creek, about 363 acres.
Total acreage in Beaver Valley, 11,360.

No measurements were obtained from Milford or from Beaver Bottoms. The only consecutive measurements of volume of the streams that have been made are given in the following table, the four streams named yielding practically the entire inflow:

TABLE 2.—*Discharge measurements of Beaver River and tributaries, in acre-feet.*

Stream.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.
1905.[a]							
Beaver River	1,994	1,493	2,460	4,046	5,341	4,327	2,446
North Creek	129	122	166	196	228	304	314
South Creek	92	78	123	167	197	232	258

Stream.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1905.[a]						
Beaver River	2,255	1,912	1,824	1,892	2,047	31,827
North Creek	332	274	240	161	135	2,631
South Creek	234	214	184	131	129	2,039

Stream.	June.	July.	Aug.	Sept.
1906.[b]				
Beaver River, June 15 to Sept. 22	9,520	7,190	4,600	2,450
Indian Creek, June 26 to Aug. 31	182	578	314	--------
North Creek, June 16 to Sept. 27	3,510	2,728	1,556	1,382
Canal at Minersville, June 21 to Sept. 21	847	2,290	2,070	1,570

[a] From weir measurements by L. L. Nunn, for the Telluride Power Company.
[b] Measurements by J. F. Hoyt.

UTILIZATION.

The surface waters are all diverted for irrigation during the summer, but the winter flow is not utilized, although some opportunity is offered for the construction of storage reservoirs. One small dam has been built by the water users of Minersville, across Beaver River in the canyon, 5 miles east of the town, but the reservoir is too small to hold the waters of even a moderate-sized flood. It might be enlarged, however, at comparatively slight cost and its usefulness greatly increased.

UNDERGROUND WATERS.

SPRINGS.

Number and distribution.—A large number of springs occur in Beaver Valley, some in the consolidated rock formations, but most of them in the unconsolidated sediments of the Beaver Lake beds. In the vicinity of Beaver they are especially numerous and some of them are not distinguishable from the seepage where the return waters of the underflow produce swampy conditions over considerable areas. They are most numerous at the foot of the gravel benches, especially where the benches are irrigated, as east of Beaver, where the return water produces a continuous flow along the foot of the bench during the irrigation season, as shown in fig. 3 (p. 48). A few of the springs have peculiarities worthy of special description, but the essential facts regarding most of them are contained in Table 6 (p. 44).

Sulphurdale.—Sulphurdale is located about 20 miles north of Beaver, a little beyond the northern border of the area shown on the map (Pl. I). The sulphur deposits, locally known as the Cove Creek beds, are located at this place. Small quantities of water which would ordinarily reach the surface as a spring, but which on account of the mining operations carried on there may be classed as mine water, issue from the sulphur beds. The water is highly mineralized, as shown by the subjoined analysis, sulphites, sulphuric acid, and iron being especially abundant. Sulphureted hydrogen (H_2S) escapes from the beds in great quantities, and the sulphuric acid is apparently the result of the oxidation of this gas. The oxygen of the air first combines with the hydrogen (H), leaving the sulphur (S), most of which remains in the solid state and constitutes the sulphur deposits; but some of the sulphur is still further oxidized to sulphur trioxide (SO_3), which combines with water (H_2O) to form sulphuric acid (H_2SO_4).

Analysis of water from Cove Creek sulphur beds.

[Parts per million. Analyst, W. M. Barr.]

Dissolved solids at 180°	8,816
Dissolved solids at 130°	10,810
Suspended matter	52
Silica (SiO_2)	124
Ferrous iron (FeO)	560
Ferric iron (Fe_2O_3)	802
Aluminum (Al)	0
Calcium (Ca)	158
Magnesium (Mg)	232
Sodium (Na) Potassium (K)	144
Carbonate radicle (CO_3)	0
Bicarbonate radicle (HCO_3)	0
Sulphate radicle (SO_4)	7,602
Free sulphuric acid (H_2SO_4)	4,523
Chlorine (Cl)	79
Nitric radicle (NO_3)	1.7
Free sulphur (S)	3.6

Constant loss of dissolved solids occurs when heated above 130°. Heated at 180°, not constant. Sample had free hydrogen sulphide (H_2S) when collected, with possible presence of sulphur dioxide (SO_2).

McKean's spring (Roosevelt Hot Spring; sec. ?, T. 27 S., R. 9 W.)—P. B. McKean's hot springs, of which there are several, are located on the western slope of the Mineral Mountains, northeast of Milford. The largest of these springs, having a discharge of about 10 gallons per minute, has been improved and a bath house built, to utilize the water for medicinal purposes. The spring is inclosed, so that the temperature of the water as it issues from the rock could not be measured, but as it issues from the pipe leading from the spring it has a temperature of 190° F. Within the spring the water is boiling and steam escapes also from crevices in the rock for a distance of several feet about the spring. The water contains a large amount of mineral in solution, as shown by the analysis in Table 9 (p. 50), and is strongly charged with hydrogen sulphide (H_2S). Much of the silica (SiO_2) contained in solution as the boiling water issues from the rocks is deposited as the water cools and does not appear in the analysis. The silica is precipitated as a light-green jelly which changes to white, spongy masses when artificially dried, but which in nature builds about the springs compact stony mounds. On analysis this deposit was found to consist entirely of silica.

The origin of the heat at this place is a matter of considerable interest. The springs are in the zone of faulting which follows the western face of the Mineral Mountains and which, although wholly in crystalline rock at this place, is well marked by a conspicuous shearing and brecciation of the rock. On the mountain slope to the east is a mass of black obsidian of recent origin, and on the eastern flank of the range occur the volcanic cones which still retain their original form in great perfection. The heat may be caused by the friction or by the crushing of rock in the fault zone or may be residual heat from a mass of intrusive lava.

Spring 4 miles north of Minersville.—This spring, like the Roosevelt Hot Spring, is located on the western slope of the Mineral Mountains in the zone of faulting. It has deposited large quantities of mineral matter, presumably silica, building up a mound subcircular in outline and about a quarter of a mile in diameter, but the water, unlike that of the Roosevelt Spring, is not notably warmer than that of ordinary springs. The water issues from the mound at several points. The flow from the main opening was estimated at 50 gallons per minute, but the total flow was not determined.

The presence of warm springs in the zone of faulting to the north at the Roosevelt Hot Spring and to the south at Minersville (Dotson's spring, described under the next heading) suggests that this may formerly have been a hot spring. The suggestion is strengthened by the presence of the large amount of silica constituting the mound. Silica is being deposited at the present time by the hot waters of the Roosevelt Spring and the Thermo springs, but apparently not by the cooler waters of the spring north of Minersville.

This spring is favorably situated for supplying the town of Minersville with drinking water. The residents of that town are now dependent on wells, the water from which is very bad, and on the river, the water from which during the summer, at least, is derived chiefly from the seepage of the lands in Beaver Basin.

The field assay of the spring water, as given in Table 6 (p. 45) shows it to contain a large amount of dissolved solids, and it would not ordinarily be considered a good drinking water. It is much better, however, than the Minersville well waters, and although it is more saline than the river water, it is from a sanitary standpoint the best supply available for the town so far as is now known.

Dotson's spring (sec. 7, T. 30 S., R. 9 W.).—R. W. Dotson's spring is located in the bank of Beaver River about a mile east of Minersville. The water issues at the rate of 57 gallons per minute from an opening on the fault at the western edge of the massive limestone of the Mineral Mountains. No use is now made of the spring except for bathing, a small tank having been built for that purpose. The water has a temperature of 97° F. and is hard and saline, as shown by the field assay given in Table 6 (p. 45).

Warm springs near Thermo.—There is a group of warm springs about 3 miles south of Thermo, a siding on the San Pedro, Los

Angeles and Salt Lake Railroad. The springs occur in two conspicuous mounds built up from the surface of the plain by silica deposited from the spring waters. The southermost mound is about 10 feet high, 160 feet wide, and 3,000 feet long, and the northernmost one is 15 to 20 feet high, 500 feet wide, and about 5,000 feet long. Water issues from these mounds at many points, but no one of the springs yields any great volume of water. The water has a temperature of 140° F. and contains hydrogen sulphide (H_2S), much of which escapes as gas. The results of a laboratory analysis of this water are given in Table 9 (p. 50). The water contains also a large amount of silica in solution, most of which is deposited at the surface when the water cools and does not appear in the analysis.

Other springs.—Data were obtained of 23 other springs. The information is largely chemical in nature and is given in Table 6, in the section describing chemical character, on pages 42–45.

SEEPAGE WATERS.

Location.—In the lower portions of Beaver Basin the surface of the ground water is at or very close to the land surface. During spring and early summer the ground-water level gradually rises, and during late summer and early autumn a considerable part of the lowlands of the valley between Beaver and Adamsville is transformed into a marsh. Many of the roads are rendered impassable and many of the fields useless for tillage or even pasturage. Nearly half of the town of Beaver was thus affected during the summer of 1906. Some of the principal streets were impassable. Water was found flowing freely from dug wells and from cellars, in some cases making houses uninhabitable. The area rendered swampy within the city is shown in fig. 3 (p. 48).

The lowlands in the vicinity of Milford and to the north, especially in Beaver Bottoms, are similarly affected, although on account of the large area of lowlands and the limited water supply swampy conditions are not so serious in the Milford region.

Volume.—The volume of return water is known to be very large in comparison with the flow of the streams, but no measurements are available at the present time. Some conception of the volume, however, may be obtained from the fact that 2,000 acres of the cultivated land of the valley are irrigated wholly by seepage waters. Besides this a large proportion of the seepage finds its way directly into the river and can not be measured separate from the stream flow. The chemical character of the seepage waters is shown in Table 5 (p. 43).

DEEP WELLS.

CLASSIFICATION.

The wells of Beaver Valley may be conveniently described in two divisions: (*a*) the bored wells, including both flowing and nonflowing wells, and (*b*) the shallow or dug wells. For the purpose of easy reference it will be convenient also to subdivide these by districts, each district being named from the town that it surrounds, except in the case of the railroad wells, which for convenience are described as being in the Milford district, although some are far from the town of Milford.

The following descriptions of the more important deeps wells are arranged in order from Beaver westward through Greenville, Adamsville, Minersville, and Milford including Beaver Bottoms.

BEAVER DISTRICT.

Barton well.—J. H. Barton has a 3-inch bored well in Beaver. It is 66 feet deep and yields an ample supply of water. Saturated sands and gravels extend more or less continuously from top to bottom. The clay partings are apparently not continuous for any great distance, as the water is under no pressure. The driller's record is as follows:

Record of J. H. Barton's well, Beaver.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	1	1
Gravel	25	26
Clay	3	29
Gravel	12	41
Clay	4	45
Gravel	21	66

Cemetery well.—There is a 2-inch drilled well at the Beaver cemetery, 180 feet deep. A gravel stratum which has water under considerable pressure, although not sufficient to produce a surface flow, was encountered at a depth of 170 feet.

Record of Beaver cemetery well.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	1	1
Gravel	3	4
Clay	7	11
Sand, gravel, and clay	169	180

Mumford well (sec. 28, T. 29 S., R. 7 W.).—George Mumford has a 2-inch bored well, 200 feet deep, located south of Beaver. The well is not now in use, but is of interest especially in showing the character of the Beaver Lake beds and for the reason that an oil stratum was penetrated at a depth of 140 feet. The evidences of oil were not sufficient, however, to indicate the presence of any large quantity.

Record of George Mumford's well, near Beaver.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	30	30
Sand	16	46
Clay	15	61
Sand	16	77
Gravel and bowlders	35	112
Clay	28	140
Gravel	35	175
Sand	25	200

Nower well (sec. 27, T. 29 S, R. 7 W.).—J. A. Nower has a 3-inch bored well, 213 feet deep, located near the point of the mesa south of Beaver. The water rises to a level 17 feet below the surface and has a temperature of 54° F.

Record of J. A. Nower's well, near Beaver.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	3	3
Clay	3	6
Sand and gravel	79	85
Clay	5	90
Alternating layers of sand and clay	123	213

Shepherd well (sec. 20, T. 29 S., R. 7 W.).—Warren Shepherd has a 4-inch bored well, 300 feet deep, located about a mile west of Beaver, in which the water stands 2 feet below the surface of the ground. It is noteworthy that in boring this well black volcanic rock, probably basalt, was penetrated, indicating that the Beaver Lake beds, like the Lake Bonneville beds, contain sheets of basalt within the sands and gravels.

Record of Warren Shepherd's well, west of Beaver.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	4	4
Gravel	2	6
Clay	6	12
Sand and gravel	31	43
Sand and gravel alternating with black volcanic rock	257	300

Wolfenden & Murdock's well (sec. 22, T. 29 S., R. 7 W.).—This well is located at the grist mill about a mile east of Beaver and is 60 feet deep. It does not reach beyond the influence of the surface changes described under the heading of shallow wells (p. 37), as do many of the deeper wells of the Beaver region, the water level being about 40 feet lower in February than in July.

Record of Wolfenden & Murdock's well, east of Beaver.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	2	2
Gravel	28	30
Clay	2	32
Sand and gravel	10	42
Clay	10	52
Sand	8	60

Other Beaver wells.—Other deep wells were found in the Beaver district, but little was learned of them further than the meager information contained in Table 3 (p. 35).

GREENVILLE DISTRICT.

Greenville school well (sec. 25, T. 29 S., R. 8 W.).—This is a 3-inch bored well located in the town of Greenville. It is 244 feet deep and encountered water under pressure at 180 and 244 feet. The surface flow is about 11 gallons per minute and the quality good.

Record of Greenville school well.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	2	2
Gravel (water-bearing)	178	180
Clay	61	241
Sand (water-bearing)	3	244

Other Greenville wells.—Several flowing wells have been bored in the vicinity of Greenville, but few definite records of the rocks penetrated are available and little information was obtained other than that given in Table 3 (p. 35).

ADAMSVILLE DISTRICT.

Griffith well (sec. 30, T. 29 S., R. 8 W.).—J. M. Griffith has three bored wells near the town of Adamsville. One is a 3-inch well 30 feet deep and flows 4 gallons per minute, another is a 2-inch well 100 feet deep and flows 3 gallons per minute, and the third is a 3-inch well 475 feet deep, which, on account of its location on ground higher than the others, does not flow. The driller's record of the third well is given below.

The artesian conditions of Beaver Basin are well illustrated at this point. Wells located in the lowest ground, whether deep or shallow, yield flowing water. Wells located on ground a few feet higher, although they penetrate much deeper beds—475 feet in this case—do not yield flowing water. The wells in the low ground flow apparently not because of pressure caused by an impervious layer overlying a water-bearing stratum, but because these wells afford places of comparatively easy escape for water which would eventually reach the surface by natural means but which is somewhat retarded on account of the friction within the beds through which it passes.

Record of J. M. Griffith's well No. 3, near Adamsville.

	Thickness.	Depth.
	Feet.	*Feet.*
Gravel	14	14
Clay	14	28
Gravel (water-bearing)	32	60
Clay	47	107
Gravel (water-bearing)	68	175
Clay	300	475

Parkinson well (sec. 28, T. 29 S., R. 8 W.).—Earl Parkinson has a 3-inch bored well, 385 feet deep, about 2 miles east of Adamsville. This well differs from most of the wells in the vicinity of Adamsville in that it does not flow, the water standing 13 feet below the surface. The material penetrated also differs notably from that in the other deep wells, being mainly fine sand and clay.

Record of Earl Parkinson's well, 2 miles east of Adamsville.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and gravel	27	27
Sand and clay	358	385

Other Adamsville wells.—Several other wells have been put down in the Adamsville district, but little information was obtained other than that contained in Table 3 (pp. 35–37).

MINERSVILLE DISTRICT.

Baker & Walker's well (sec. 8 (?), T. 30 S., R. 10 W.).—This well is located about 5 miles west of Minersville. It is a 3-inch bored well 223 feet deep. Water-bearing gravel was encountered at a depth of 185 feet, but the water is not under pressure.

Record of Baker & Walker's well, 5 miles west of Minersville.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay soil	10	10
Gravel	165	175
Clay	10	185
Gravel (water-bearing)	5	190
Clay	33	223

Goodson well (sec. 8, T. 30 S., R. 10 W.).—E. J. Goodson has a 3-inch bored well, 124 feet deep, about 6 miles west of Minersville. Water was found from 96 feet downward, but is under no pressure. A well belonging to Henry Baker, located about 2 miles southwest of Mr. Goodson's well, is 210 feet deep, with water under little pressure at 180 feet.

Record of E. J. Goodson's well, 6 miles west of Minersville.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	6	6
Gravel	84	90
Clay	6	96
Gravel (water-bearing)	10	106
Sand and clay	18	124

Van Patten well.—F. A. Van Patten has a 3-inch drilled well, 125 feet deep, at Minersville. Water was not found below a depth of 95 feet, and the casing was drawn back to that depth.

Record of F. A. Van Patten's well, Minersville.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	1	1
Gravel	24	25
Alternating layers of clay, sand, and gravel (water-bearing)	90	115
Clay	10	125

Other Minersville wells.—There are several bored wells in Minersville, but little of interest was learned of them. The scanty information is to be found in Table 3 (p. 36).

MILFORD DISTRICT.

Milford town well.—The town of Milford is supplied with water from a bored well 425 feet deep, located at the foot of the gravel bench which occurs at the west edge of the town. The upper 300 feet of the well is cased with 6-inch pipe, from the lower end of which a 4-inch pipe extends to the bottom of the well, the water coming entirely from a depth of 425 feet. The water has a pressure of 6 pounds per square inch at the surface, flows 30 gallons per minute, and has a temperature of 72° F.

The natural flow of the well is not sufficient to supply the town and the water is pumped by a 10-horsepower gasoline engine to a cement reservoir, 28 by 72 feet and 6½ feet deep, located on the gravel bench 60 feet above the town. The pump ordinarily discharges 156 gallons per minute, and the well readily yields this amount. No determination has been made of the maximum possible yield of the well, but it would apparently supply much more than 156 gallons per minute.

The surface water at Milford is brackish and for this reason is cased out of the town well. The analysis in Table 9 (p. 50) shows that the water from the depth of 425 feet is very good for domestic purposes.

Lewis well.—A. B. Lewis has a bored well in the town of Milford that is cased to a depth of 450 feet with 4-inch pipe, inside of which a 2-inch pipe extends to a depth of 750 feet. From the outer pipe water flows at the rate of 37 gallons per minute and has a temperature of 80° F. Water also flows from the inner pipe at the rate of 2 gallons per minute, and since it is surrounded by the water of the outer pipe it issues with the same temperature, 80° F. The water from the 750-foot level differs from that at 450 feet in containing much more mineral matter in solution, as shown in Table 3 (p. 36), and also in containing hydrogen sulphide (H_2S).

Record of A. B. Lewis's well, Milford.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	12	12
Gravel	48	60
Clay and sand in alternating layers	390	450
Clay	80	530
Quicksand	5	535
Clay	215	750
Sand		(?)

Winberg well.—A. W. Winberg has a 2-inch bored well at the steam laundry in Milford. It is 326 feet deep and penetrates water-bearing strata at depths of 260, 285, 310, and 326 feet, all four beds yielding flowing water. The pressure at the mouth of the well is 6 pounds per square inch and the flow 9 gallons per minute. The quality of the water is excellent and is practically the same as that from the town well.

Record of A. W. Winberg's well, Milford.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	16	16
Gravel (water-bearing)	44	60
Alternating beds of clay, sand, and gravel (water-bearing)	266	326

Railroad well.—The San Pedro, Los Angeles and Salt Lake Railroad has three flowing wells at Milford. Two of them are 2-inch wells about 400 feet deep, each discharging 18 gallons per minute; the third, a 12-inch well, 310 feet deep, located near the railroad station, ordinarily flows 30 gallons per minute, the pressure at the surface being about 6 pounds per square inch. Ground water here occurs at a depth of 8 feet and artesian flows at 170 and 310 feet. The flow is not sufficient to supply enough water for railroad use at this station, and water is pumped from the 12-inch well at the rate of 270 gallons per minute. The driller's record of this well follows, and an analysis of the water is given in Table 10 (p. 51).

Record of the San Pedro, Los Angeles and Salt Lake Railroad 12-inch well, Milford.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	4	4
Sand	6	10
Blue clay	22	32
Sand	33	65
Blue clay	10	75
Sand and gravel	15	90
Blue clay	25	115
Hardpan	4	119
Quicksand	35	154
Blue clay	15	169
Sand (artesian flow)	5	174
Red clay	81	255
Quicksand	10	265
Sand	5	270
Clay	8	278
Sand	10	288
Yellow clay	17	305
Cemented gravel (artesian flow)	5	310

Milwaukee Leasing Company's well (sec. 31(?), T. 28 S., R. 11 W.).—This well is located about 8 miles southwest of Milford, at the Milwaukee Leasing Company's stamp mill. It was originally a 6-inch drilled well, 90 feet deep, with water at a depth of 45 feet. Later an open shaft was dug to water level. The water is pumped for use in the stamp mill in sufficient quantity to supply the 20 stamps operated.

East and south of the mill and on lower ground water is found under considerable pressure. Large so-called artesian springs are reported there, and one well drilled several years ago still flows to some extent.

Majestic Copper Mining and Smelting Company's wells.—There are four flowing wells at the smelter 2 miles south of Milford, 95, 340, 465, and 470 feet deep. The smelter is not now in operation, and little information regarding the wells could be obtained. The flow is slight, owing probably to the location of the wells on a bench several feet above the valley bottom.

Wells in Beaver Bottoms.—J. C. White reports 20 flowing wells in Beaver Bottoms, many of them bored by himself. Water having pressure sufficient to produce a slight surface flow from wells located on the lowest ground occurs in beds of sand and gravel at depths of 180 to 200 feet below the surface. The wells are all very small, the casing varying from 1 to 2 inches in diameter, and the flow is only 1 to 3 gallons per minute.

An attempt was made several years ago to find other water-bearing strata, and a well was sunk on the Ryan ranch near Read (formerly Smith's station) to a depth of 860 feet. The sediment encountered was all very fine. Some sand was found with the clay to a depth of 300 feet, but below this the material penetrated was wholly clay.

The waters of Beaver Bottoms are strongly charged with saline matter, the artesian waters more so than the surface waters. In this respect the relations at Milford, 10 miles to the south, are reversed. The surface waters of Milford and of Beaver Bottoms probably do not differ greatly in salinity, but the artesian waters of the latter place are so strongly saline that the surface waters seem good by comparison. The field assays of water from James Forgie's dug well, 18 feet deep, and artesian well, 215 feet deep, are shown in Table 3 (p. 36).

A laboratory analysis of water from J. C. White's artesian well, 185 feet deep, located in Beaver Bottoms about 2 miles east of James Forgie's well, is given in Table 9 (p. 50).

RAILROAD WELLS OUTSIDE OF BEAVER VALLEY.

No great thickness of the Lake Bonneville beds is exposed at the surface in the Escalante Desert, and the character of the sediments is best shown by well records. There are few carefully kept records available within the limits of the area described in this paper, and for this reason it is thought advisable to include some obtained from places outside of Beaver County, but within the limits of the Escalante Desert, and therefore having a direct bearing on the discussion of underground waters in Beaver Valley. Several wells have been bored for the San Pedro, Los Angeles and Salt Lake Railroad in the Escalante Desert between Beryl and Lynn, the locations of which are shown in fig. 1 (p. 7). J. A. Shanahan, one of the officials of the railroad, has very kindly furnished the following information for use in this report.

Beryl.—The railroad has a 13-inch bored well at Beryl, 208 feet deep. Water was encountered at depths of 23, 180, and 203 feet and rises within 19 feet of the surface. During a pumping test of twenty-four hours the well is said to have yielded 183 gallons of water per minute.

Record of the San Pedro, Los Angeles and Salt Lake Railroad well at Beryl.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	8	8
Clay and gravel	8	16
Gravel (water-bearing)	7	23
Gravel and clay	15	38
Clay	80	118
Clay and gravel	57	175
Gravel (water-bearing)	5	180
Clay	20	200
Sand (water-bearing)	3	203
Clay	5	208

Lund.—The well at Lund, completed in 1903, is 585 feet deep. Flowing water was encountered at five horizons, as shown by the following log. The well is cased with 12-inch pipe at the top, but this is reduced below to 10, 8, and finally to 6 inches. The well flows 20 gallons per minute and when pumped yields 100 gallons per minute, with a temporary depression of the water surface of less than 20 feet.

Record of the San Pedro, Los Angeles and Salt Lake Railroad well at Lund.

	Thickness.	Depth.
	Feet.	*Feet.*
Sand	2	2
Clay	4	6
Gravel (small flow)	6	12
Coarse gravel	4	16
Hardpan and clay	49	65
Quicksand	4	69
Blue clay	80	149
Sand	4	153
Red clay	12	165
Blue clay	159	324
Red rock	6	330
Blue clay	70	400
Quicksand	20	420
Green shale rock	10	430
Clay and sand	10	440
Sand (small flow)	3	443
Blue clay	11	454
Clay and sand	8	462
Sand (large flow)	13	475
Clay	3	478
Sand	6	484
Red clay	2	486
Very fine sand	8	494
Red clay	10	504
Dark clay	4	508
Blue clay	14	522
Very fine sand	3	525
Blue clay	2	527
Fine sand (small flow)	3	530
Brown clay	19	549
Sand	1	550
Brown clay	23	573
Coarse sand	10	583
Coarse gravel (large flow)	2	585
Blue clay		

Thermo.—The well at Thermo, completed in 1905, is 401 feet deep and encountered water at several horizons. It is cased with 12-inch pipe to a depth of 337 feet. During a pumping test the well supplied 100 gallons of water per minute, with a temporary lowering of the water surface of less than 16 feet.

Record of the San Pedro, Los Angeles and Salt Lake Railroad well at Thermo.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	5	5
Fine gravel	5	10
Red sand	3	13
White clay	25	38
Fine gravel (water-bearing)	3	41
White clay	54	95
Red clay	45	140
Quicksand	27	167
Red clay	13	180
Sand and clay	25	205
Blue clay	20	225
Sand	10	235
Clay	9	244
Clay and gravel	31	275
Clay and sand	41	316
Clay and gravel	12	328
Sand	13	341
Clay and gravel (water-bearing)	60	401

Neels.—The well at Neels, completed in 1906, is 1,998 feet deep. Water was encountered at several horizons, as indicated in the following log, but nowhere under pressure enough to force it to the surface. All of the water is said to have been hot, and steam escaped freely from the well during the process of boring. The water at every horizon was found to be of poor quality, although a large quantity was obtained, 260 to 300 gallons per minute being pumped during a test lasting continuously for twenty-four days. This test was made with the hope that continuous pumping would clear the well and improve the quality of the water, but no improvement was shown. An attempt was then made to sink the well deeper into the granite, but the rock was found to be fractured and the crevices deflected the drill laterally and otherwise proved so bothersome that the well was abandoned.

A slight amount of oil was found at several horizons in this well, and gas under great pressure was encountered at a depth of 1,802 feet.

Record of the San Pedro, Los Angeles and Salt Lake Railroad Well at Neels.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface soil	4	4
Sedimentary (alkali)	5	9
Fire clay	10	49
Water-bearing quicksand	9	58
Shale and soapstone	21	79
Rock (sedimentary)	6	85
Water-bearing quicksand	3	88
Soapstone	11	99
Soapstone with fossil bowlders	39	138
Water-bearing quicksand	4	142
Fire clay	12	154
Blue waxy clay	34	188
Gray shale and clay mixed	7	195
Gray waxy clay	36	231
Lava rock	12	243
Blue waxy clay	12	255
Sedimentary sandstone	6	261
Blue waxy clay	25	286
Water-bearing quicksand	6	292
Blue waxy clay	28	320
Water-bearing quicksand	7	327
Sedimentary sandstone	10	337
Yellow clay	16	353
Water-bearing quicksand	5	358
Yellow clay	27	385
Blue waxy clay	110	495
Yellow clay	15	510
Sedimentary sandstone	24	534
Blue waxy clay	17	551
Soapstone	50	601
Blue waxy clay	11	612
Silt	8	620
Water-bearing quicksand	3	623
Yellow clay	53	676
Sedimentary sandstone	12	688
Yellow clay	34	722
Blue waxy clay	117	839
Yellow clay	9	848
Blue waxy clay	210	1,058
Blue shale (sand mixed)	18	1,076
Blue waxy clay	13	1,089
Blue shale	45	1,134
Blue shale (sand mixed); yielded hot water	71	1,205
Red shale	12	1,217
Blue shale	70	1,287
Red shale	24	1,311
Blue shale	28	1,339
Red "keel" stone	6	1,345
Water, sand, gravel, and bowlders	70	1,415
Sedimentary sandstone, brown	35	1,450
Red sandstone	95	1,545
Red shale, burned	35	1,580
Trap rock, dark brown	36	1,616
Red shale, burned	56	1,672
Lava rock with calcite crystals	14	1,686
Red sandstone	68	1,754
Red clay, sticky	48	1,802
Volcanic deposit, ash, and bowlders; gas under pressure sufficient to raise 6,200 pounds of tools 400 feet	105	1,907
Bowlders, cemented	6	1,913
Cavity	9	1,922
Bowlders	22	1,944
Cavity	6	1,950
Granite with crevices and gas	48	1,998

Oasis.—The well at Oasis, completed in 1905, is 656 feet deep and is cased with 12-inch pipe to a depth of 73 feet, below which 10-inch casing extends to the bottom of the well. Water under pressure sufficient to cause it to flow at the surface was encountered at ten different horizons, and there seems to be an unusual quantity of water present. During a pumping test the well supplied 200 gallons per minute, with a temporary depression of the water surface of only

3 feet. At no horizon, however, was the water found to be suitable for boiler purposes. A drinking water of good quality, prized for its mineral qualities, occurs at a depth of 350 feet, and the casing was shot off, so that the present flow of 30 gallons per minute comes entirely from this depth. The drinking water used on the dining cars and in the offices of the railroad is supplied by this well.

Record of the San Pedro, Los Angeles and Salt Lake Railroad well at Oasis.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	8	8
Sand	3	11
Blue clay	49	50
Sand	10	60
Lime and shells	20	80
Quicksand	45	125
Blue clay	40	165
Sand	5	170
Blue clay	20	190
Red clay	45	235
Sand	15	250
Blue clay	20	270
Red clay	25	295
Sand	13	408
Sandstone	4	412
Blue clay	68	480
Sand	11	491
Red clay	9	500
Blue clay	27	527
Quicksand	3	530
Clay and sand	29	559
Black sand	3	562
Clay and gravel	13	575
Clay	23	598
Cemented gravel	12	610
Soft sandstone	7	617
Clay	6	623
Rock	2	625
Clay	15	640
White clay	16	656

Lynn.—The well at Lynn, completed in 1905, is 235 feet deep and is cased with 12-inch pipe to a depth of 225 feet. The water does not flow at the surface, but has been pumped at the rate of 90 gallons per minute.

Record of the San Pedro, Los Angeles and Salt Lake Railroad well at Lynn.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	8	8
Gravel	10	18
Sand	12	30
Sand and gravel	10	40
Sand	20	60
Blue clay	95	155
Blue sandy clay, water bearing	60	215
Sand	10	225
Coarse gravel, water bearing	10	235

STATISTICS OF DEEP WELLS.

The following table comprises such information in regard to the deep wells of Beaver Valley as can be conveniently presented in this form:

TABLE 3.—*Statistics of deep wells in Beaver Valley.*

[Chemical determinations in parts per million. Wells marked with asterisk not on Pl. I.]

No. on Pl. I.	District and owner.	Location.	Character of well.	Depth.	Depth to water horizons.	Flow per minute.	Temperature.	Iron (Fe).	Total alkalinity as $CaCO_3$.	Alkaline carbonate.	Sulphate radicle (SO_4).	Total hardness ($CaCO_3$).	Chlorine (Cl).	Remarks.
	BEAVER DISTRICT.			*Feet.*	*Feet.*	*Gals.*	° *F.*							
1	Barton, J. H	Beaver	Nonflowing	66	29 45		52	0	243	0	<35		60	
2	Beaver cemetery	do	do	180	170									
3	Hurst, Wm	do	do					1	255	0	<35		28	
4	McGregor, D. A	do	do	60			55	0	142	0	Tr.		120	
5	Murdock	do		40				0	203	0	Tr.		58	Low in February, high in July; variation, 24 feet.
6	Mumford, George	Sec. 28, T. 29 S., R. 7 W	Nonflowing	200										Well not in use.
7	Nower, J. A	do	do	213			54							
8	Shepherd, Warren	Sec. 20, T. 29 S., R. 7 W	do	300										
*9	Tolton, J. F	Beaver	do	62	45 61		51	0	203	0	0		60	
	GREENVILLE DISTRICT.													
10	Barton, S. R	Sec. 36, T. 29 S., R. 8 W	Flowing	314	200 314	7	74	0	142	0	Tr.	56	20	Low in February, high in July.
11	Blackner, O	Sec. 35, T. 29 S., R. 8 W	do	23				0	364	0	<35		30	
12	Edwards, Wm	Sec. 34, T. 29 S., R. 8 W	Nonflowing	95	36 44 95			Tr.	446	0	<35		106	
13	Farnsworth, G. T	Sec. 35, T. 29 S., R. 8 W	do	35	5			0	405	0	<35		81	Low in February, high in June.
14	Greenville school	Greenville	Flowing	244	180 244	11	68	0	242	0	Tr.	90	10	
15	Murdock, J. M	Sec. 24, T. 29 S., R. 8 W	do	163		15	55	0	132	0	Tr.	75	15	
	ADAMSVILLE DISTRICT.													
16	Griffiths, J. M	Sec. 30, T. 29 S., R. 8 W	Flowing	100		3	52	0	162	0	<35	65	50	
17	do	Sec. 19, T. 29 S., R. 8 W	do	30		4	51	Tr.	240	0	<35		60	
*18	do	Sec. 30, T. 29 S., R. 8 W	Nonflowing	475	8 37 100									

TABLE 3.—*Statistics of deep wells in Beaver Valley*—Continued.

No. on Pl. I.	District and owner.	Location.	Character of well.	Depth.	Depth to water horizons.	Flow per minute.	Temperature.	Iron (Fe).	Total alkalinity as $CaCO_3$.	Alkaline carbonate.	Sulphate radicle (SO_4).	Total hardness ($CaCO_3$).	Chlorine (Cl).	Remarks.
				Feet.	*Feet.*	*Gals.*	*° F.*							
	ADAMSVILLE DISTRICT—Con.													
19	Grimshaw, F. T.	Sec. 30, T. 29 S., R. 8 W	Flowing											
*20	Gunn, Fred T	Sec. 30, T. 29 S., R. 8 W	do			60								
21	Johnson, Sam'l	Sec. 30, T. 29 S., R. 8 W	Nonflowing	32	14 32			1	364	0	<35	194	80	
22	Joseph, J. H	Sec. 30, T. 29 S., R. 8 W	do	50			55							
23	Parkinson, E	Sec. 28, T. 29 S., R. 8 W	do	385			53							
	MINERSVILLE DISTRICT.													
24	Baker, H. F	Minersville	Nonflowing				56	0	324	0	113		101	
25	Baker, Henry	Sec. 16, T. 30 S., R. 10 W	do	210	180									
26	Baker & Walker	Sec. 8, T. 30 S., R. 10 W	do	223	185									
*27	Dotson, R. W	Sec. —, T. 30 S., R. 10 W	do	53				1	447	0	168	230	131	
*28	do	Minersville	do					Tr.	360	0	35	272	80	
29	Goodson, E. J	Sec. 7, T. 30 S., R. 10 W	do	124	93									
*30	Hollingshead, S. B	Minersville	do	100				Tr.	223	0	328	550	808	
*31	Kelsey, W. M	do	do	56	25 36 58		56	12	295	0	191		446	
*32	Marshall, Geo	do	do	38			55	0	358	0	222	689	242	
*33	Murdock, L. E	do	do	42				0	324	Tr.	35		40	
*34	Van Patten, F. A	do	do	125	95		56	0	326	0	56		95	
35	Walker, H. A	Sec 15, T. 30 S., R. 10 W	do	180	180		55	0	370	0	71		161	
	MILFORD DISTRICT.													
36	Forgie, John	Milford	Flowing	336	150 315	25	65	0	140	Tr.	0		13	Flow ceases when railroad well 200 yards away is pumped.
37	do	Sec. 18, T. 28 S., R. 10 W	do	357		25	78	0	141	0	Tr.		14	
38	do	Sec. 8, T. 28 S., R. 10 W	do	381	345	13	65							
39	Forgie, James	Sec. 7, T. 26 S., R. 10 W	do	215				4	466	0	36		1,752	
*40	do	Sec. 7, T. 26 S., R. 10 W	Dug	18				0	648	283	0		662	
*41	Grace Bros	Milford	Nonflowing	48			60	0	162	0	35	216	148	
42	Harrington, Mrs	do	do	55	43									
43	Holderman & Sons	Sec. 18, T. 28 S., R. 10 W	Flowing	420										
*44-45	Lewis, A. B	Milford	do	750	300 750	37 2	80 80	0 0	145 283	0 0	0 0		17 35	Sulphur water from bottom.

*46	McCauley, J. D	do	Flowing	280	.....	7	68	.....	.....	.....	.....	.....	.....	Flow has decreased from 17 gallons per minute.
*47	McKean, P. B	do	Nonflowing	60	.....	.....	59	Tr.	152	0	38	.....	181	
*48	Milford town	do	Flowing	425	.....	30	72	0	162	0	Tr.	69	13	117 gallons per minute pumped.
*49	Milford school	do	Dug	35	.....	.....	.....	.....	.....	.....	.....	.....	.....	
*50	Milwaukee Leasing Company	T. 28 S., R. 11 W	Nonflowing	90	45	.....	.....	.....	.....	.....	.....	.....	.....	Supplies a 20-stamp mill.
*51	Mowre, A. W	Milford	do	45	.....	.....	.....	0	162	0	41	.....	424	
52	Murdock, J. M	Sec. 18, T. 26 S., R. 10 W	Flowing	180	.....	.....	.....	0	263	0	0	.....	836	
53	Ryan ranch	Sec. 5, T. 26 S., R. 10 W	do	860	.....	.....	.....	.....	.....	.....	.....	.....	.....	Not used.
54	San Pedro, Los Angeles and Salt Lake R. R.[a]	Milford	do	310	170 310	30	71	0	160	0	Tr.	49	12	270 gallons per minute pumped.
*55	do	do	do	400	.....	18	.....	0	142	0	Tr.	.....	15	
*56	do	Beryl	Nonflowing	208	.....	.....	.....	.....	.....	.....	.....	.....	.....	183 gallons per minute pumped.
*57	do	Lund	Flowing	585	.....	20	.....						.....	100 gallons per minute pumped.
58	do	Thermo	Nonflowing	401	.....	.....	.....	.....	.....	.....	.....	.....	.....	Do.
*50	do	Neels	do	1998	.....	.....	.....	.....	.....	.....	.....	.....	.....	300 gallons per minute pumped.
*60	do	Oasis	Flowing	656	.....	30	.....	.....	.....	.....	.....	.....	.....	200 gallons per minute pumped.
*61	do	Lynn	Nonflowing	235	.....	.....	.....	.....	.....	.....	.....	.....	.....	90 gallons per minute pumped.
62	Tanner, E	Sec. 5, T. 28 S., R. 10 W	Flowing	286	.....	8	71	0	101	0	<35	.....	38	
*63	do	Sec. 5, T. 28 S., R. 10 W	do	370	.....	8	67	.....	.....	.....	.....	.....	.....	
64	Whitaker, Arthur	Sec. 32, T. 27 S., R. 10 W	do	403	.....	18	.....	.....	.....	.....	.....	.....	.....	Many water-bearing strata.
*65	Winberg, A. W	Milford	do	326	260 285 310 326	9	68	0	130	Tr.	<35	.....	24	Pressure 7 pounds per square inch.
66	White, J. C	Sec. 17, T. 26 S., R. 10 W	do	185	.....	.....	.....	0	666	383	0	.....	1787	

[a] For exact analyses of water from railroad wells see Table 10 (p. 51).

SHALLOW WELLS.

Tabulated data.—There is little to be said of individual shallow wells and the available information is probably best presented in tabular form. For convenience of reference these wells are arranged like the deep wells, by districts, and in order to avoid duplication the chemical analyses described on page 46 are included in the table.

TABLE 4.—*Statistics of shallow wells in Beaver Valley.*

[Chemical determinations in parts per million.]

District and owner.	Location.	Depth.	Fluctuation of water surface.	Iron (Fe).	Total alkalinity at $CaCo_3$.	Alkaline carbonates.	Sulphate radicle (SO_4).	Chlorine (Cl.).	Remarks.
BEAVER DISTRICT.		*Feet.*	*Feet.*						
Ash, Joseph	Beaver	24	16	0	223	0	Tr.	35	Low in February, high in July.
Atkins, Alice	do			0	281	0	<35	70	
Baldwin, M. D	do			0	255	0	0	24	
Barrachouch, J	do			2	253	0	<35	50	
Bastian, L. H	Sec. 21, T. 28 S., R. 7 W	29	14	0	142	0	<35	19	Low in February, high in June.
Boyter, A	Beaver	52	44						Low in February, high in July.
Do	Sec. 9, T. 29 S., R. 7 W	8	7						Do.
Burt, William	Beaver			0	264	0	0	28	
Briggs, John	Sec. 2, T. 29 S., R. 7 W	50							Water only during irrigation.
Day, Joseph	Sec. 35, T. 28 S., R. 7 W	14	10	Tr.	122	0	<35	15	Low in February, high in July.
Dean, Jeddy	Beaver	22	19	0	223	0	0	20	Do.
Farnsworth, R	Sec. 21, T. 28 S., R. 7 W	23		Tr.	157	0	<35	186	Do.
Farnsworth, L. E	Do	35	18						Do.
Farnsworth, W. H	Beaver			Tr.	233	0	<35	198	
Gale, O. W	Sec. 3, T. 29 S., R. 7 W	30	22						Do.
Gale, M. H	Sec. 4, T. 29 S., R. 7 W	42	15	0	207	0	<35	30	Do.
Geordy, David	Beaver	37	29						Do.
Grimshaw, D	Do	33	30	0	273	0	Tr.	43	Do.
Goodwin, I. S	Do			0	233	0	Tr.	51	
Hanson, W. L	Sec. 28, T. 29 S., R. 7 W	10	6	0	202	0	0	10	Do.
Harris, H	Beaver			Tr.	182	0	<35	80	
Harris, L. H	Do			Tr.	252	0	Tr.	28	
Harris, Lydia	Do			0	283	0	Tr.	60	
Huntington, Mrs. E	Do			0	195	0	Tr.	53	
Hodges, C. H	Sec. 3 T. 29 S., R. 7 W	30	13						Do.
Howd, S. F	do			3	253	0	Tr.	47	
Jackson, Joe	do			0	298	0	<35	141	
Jones, J. F	Beaver	24	20	0	273	0	<35	80	Sample taken Aug. 24, 1906. Low in February, high in July.
Do	do			0	243		<35	65	Sample taken Aug. 2, 1906.
Lawrence, A. L	do			Tr.	250	0	<35	70	
Manhardt, W. M	Sec. 31, T. 28 S., R. 6 W	20	15	0	152	0	<35	24	Low in February, high in July.
Mansfield, E. M	do	47	31	0	223	0	Tr.	25	
Morgan, Edward	do			0	234	0	Tr.	33	
Muir John J	do			0	245	0	<35	63	

Mumford, Geo	Sec. 28, T. 29 S., R. 7 W	40	10						Low in February, high in July; water brackish.
Neilson, N. B	Beaver		42	0	253	0	0	49	Low in February, high in July.
Okenden, C	do			0	241	0	<35	303	
Owens, G. E	Sec. 22, T. 29 S., R. 7 W	17	12	0	253	0	0	35	Do.
Paice, Geo	Beaver	33	29						Do.
Rees, Watkin	do	25	22	0	243	0	<35	46	Do.
Robinson, Eliza	do			2	223	0	Tr.	40	
Smith, Seth W	do			0	243	0	0	65	
Stony, F. J	do			0	304	0	Tr.	18	
Swindelhurst, E. B	do			0	242	0	Tr.	35	
Thompson, Wm	do	46	38						Low in January, high in July.
Twitchell, W. A	Sec. 31, T. 29 S., R. 6 W	20	15						Variation caused wholly by irrigation.
Twitchell, D. F	Sec. 21, T. 28 S., R. 7 W	15	4						Low in February, high in July; water brackish.
Valentine, Jos	Sec. 35, T. 28 S., R. 7 W	12	4						
Wolfenden, C	Beaver			0	235	0	Tr.	30	
Whitaker, O. A	do	44	3						Low in February, high in July.
Wilden, F	do	13	8	0	121	0	0	25	Do.
Woodbury, Chas	Sec. 10, T. 29 S., R. 7 W	101							Water only during irrigation season.
Wolfenden & Murdock	Beaver	60	40	0	344	0	<35	70	
Woolsey, D. M	Sec. 35, T. 28 S., R. 7 W	85							No water.
GREENVILLE DISTRICT.									
Edwards, William	Sec. 25, T. 29 S., R. 8 W	5	1	0	308	0	<35	63	Low in September, high in July; hardness 263.
Farnsworth, G. T	Sec. 35, T. 29 S., R. 8 W	35	0	0	405	0	<35	81	
Murdock, John M	Sec. 24, T. 29 S., R. 8 W	20	0						Water brackish.
ADAMSVILLE DISTRICT.									
Johnson, C	Sec. ?, T. 29 S., R. 8 W	7	7	Tr.	496	0	<35	141	Low in September, high in June.
Jones, Cutler & Fennemore	Sec. 32, T. 29 S., R. 8 W	49	20	Tr.	284	0	Tr.	121	Water brackish; improves during irrigation.
Stewart, Lewis	Sec. 29, T. 29 S., R. 8 W	23		0	567	0	48	132	Low in February, high in July.
MINERSVILLE DISTRICT.									
Banks, J. R	Minersville	28	16	0	324	0	<35	41	
Banks, W. H	do	21		0	370	0	265	232	Total hardness 438.
Burke, Lydia	do	13	7	0	370	0	168	125	Low in September, high in June.
Dotson, R. W	do	23	7	Tr.	360	Tr.	<35	80	
Minersville town well	T. 30 S., R. 11 W	80		2	125	0	0	50	
Walker, H. A	Minersville	23	5	0	370	0	85	161	

Water-bearing material.—The material near the surface of the Beaver Lake beds consists mainly of coarse sand and gravel and is but slightly consolidated. Some of it is made up of sand and rounded pebbles, presumably lake sediments, deposited before Beaver basin was drained by the down cutting of the river in the canyon at Minersville, and some of it is coarse and subangular, deposited by the streams. In some places the gravels are exposed at the surface over considerable areas and in others they are covered with a thin veneer of soil. In no place observed had soil or silt accumulated to any great depth. The wells are nearly all in gravel, as illustrated in Mr. Boyter's well, a record of which is given below:

Record of A. Boyter's well, Beaver.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	1	1
Gravel	24	25
Clay	2	27
Gravel	24	51
Sand	1	52

The abundance of unconsolidated gravel near the surface and the scarcity of surface soil are due, in part at least, to the steep grade of the streams, causing current velocities that preclude the possiblity of deposition of the finer materials. The gravels exposed at the surface allow the rain water, the stream water, and the irrigation water to sink readily into the ground and the absence of fine material from the gravel beds makes it possible for water to move rapidly through them.

Where the Beaver Lake beds are exposed to view through any considerable thickness, as in the bench south of Beaver and in similar exposures to the east and north, they are found to contain a much greater proportion of fine material than is encountered in digging wells in the center of the valley. This is probably due to the varying conditions under which the material was accumulated. The older parts of the Beaver Lake beds were laid down in Beaver Lake, and coarse and fine materials were deposited together. When the lake ceased to exist because of the filling with sediment on the one hand and the down cutting of the outlet between Adamsville and Minersville on the other, the river deposited only the coarser material within Beaver Basin, carrying the finer material through the outlet to form part of the Lake Bonneville beds of the Escalante Desert. There is furthermore ample evidence in Beaver basin, as in other places throughout the semiarid region of western America, that varied conditions of erosion and deposition have prevailed during recent geologic time. The streams were sometimes depositing sand and gravel and building up the floors of the valleys and at other times eroding away the material previously laid down. Both operations have had a tendency to cause coarse material to accumulate in the center of the valley. While the river was building up its valley, the finer sediments were carried through to Escalante Bay and the coarser material was dropped within the basin. On the other hand, while the river was eroding, it worked over the sediments previousy deposited in Beaver Basin, bearing away such material as it was able to carry and leaving the heavier rock fragments. In this way the coarser material accumulated in the center of the valley both by direct deposition and by surface concentration of the gravels.

West of Minersville, however, a different set of conditions prevailed. The water-bearing materials there are the lake sediments of the Lake Bonneville beds. The river has deposited comparatively little sediment and there has been practically no erosion since the beds were formed. The sediments in the midst of the desert, extending from the surface to some unknown depth, consist of clay, sand, and fine gravel, as shown by the well records previously given; along the margins they consist of coarser material derived from the neighboring hills. Since the Lake Bonneville beds are lake deposits, the various layers are presumably persistent over considerable areas. For these reasons the waters are mainly artesian and the surface waters of comparatively little importance, as stated in the description of the deep wells of the Milford district.

Changes in water level.—On account of the coarseness and unconsolidated condition of the gravels in Beaver Basin, the water moves readily through them and great changes of level are caused at different times of the year. During the winter much of the precipitation is retained in the mountains in the form of snow and little water is spread over the land for irrigation. There is, therefore, in this season a minimum contribution to the underground supply and a general low-water condition prevails in the shallow wells, the lowest stage being reached in February. In the spring, however, the melting snow supplies large volumes of water to the streams, and this in turn is not only spread over the land for irrigation purposes, but great quantities find their way into the gravels, raising the level of the underground water, which reaches its highest stage in July. The extreme difference in level is variously reported, as shown under "Remarks" in Table 4 (pp. 38–39), the greatest variation of water level being 42 feet.

This rise of the underground water causes serious damage in the lowlands, especially during seasons of more than ordinary rainfall, such as the summer of 1906. During the writer's investigations in Beaver Valley from July to September of that year the lowlands of the valley were in a boggy condition approaching that of a swamp.

Fields were observed with crops that could not be harvested because of the swampy condition. Roads were rendered impassable and animals were mired on land which had formerly been dry. In the town of Beaver many of the dooryards were swampy and water filled the cellars and flowed freely from the dug wells, which during the winter have water only at depths of 25 or 30 feet. Many of the streets were impassable, and a general unhealthful condition prevailed throughout the town. The area within the town that was made more or less swampy by the return waters during July, 1906, is shown in fig. 3 (p. 48). The long arm shown on this map extending northward to the Beaver cemetery is due to the irrigation of the gravel bench east of the town, the return waters issuing at the foot of the bench.

CHEMICAL CHARACTER OF WATERS.

METHODS OF DETERMINATION.

A chemical outfit for determination of some of the principal elements contained in ordinary waters was taken to Beaver Valley, and a large number of the waters were tested. These field assays, though much less accurate than those made in the laboratory, give a fairly adequate conception of the chemical character of the waters. Although they are not sufficiently exact to be relied on for the minor differences in character, the major differences are plainly brought out, as will be observed by an inspection of the various tables that follow.

In addition to the field assays, laboratory analyses were obtained from three sources: (1) samples of water were sent to the laboratory of the United States Geological Survey and analyzed by W. M. Barr, of the water resources branch; (2) sanitary analyses of four samples of water were made by Herman Harms, of Salt Lake City, State chemist of Utah; and (3) the analyses of water used by the San Pedro, Los Angeles and Salt Lake Railroad have been kindly furnished for this report by E. G. Tilton, chief engineer of the road.

STREAMS.

The waters of the streams at their points of issuance from the hills are very pure. Farther down the valley they become more highly charged with saline matter, as shown by the assays in Table 5. The chlorine of Beaver River, for example, increases from 9 to 53 parts in a million parts of water between the mouth of the canyon and Minersville, a distance of only 17 miles. There is also a marked change toward alkalinity, the carbonates increasing from 71 to 225 parts in the same distance. It is furthermore to be noted that the alkaline carbonates (sodium carbonate and potassium carbonate), which are not contained in the waters as they issue from the hills, are present farther downstream. This is probably caused by the entrance of seepage or return waters that are more highly charged with salts than the streams. The spring waters of the valley are also more saline than the streams and contribute in some measure to the increasing salinity toward the lower parts of the valley.

TABLE 5.—*Field assays of stream waters.*

[Parts per million.]

Source.	Location.	Iron (Fe).	Total alkalinity as $CaCO_3$.	Alkaline carbonates.	Sulphate radicle. (SO_4)	Total hardness as $CaCO_3$.	Chlorine (Cl).
Beaver River	4 miles east of Beaver	0	71	0	<35	42	9
Do	Greenville	0	203	21	<35	160	30
Do	Minersville	0	182	43	<35	......	53
Canal	Beaver	0	71	0	<35	......	15
North Creek	North of Beaver	0	61	0	<35	......	3
North Creek Canal	do	0	71	0	<35	......	10
North Creek	Greenville	Tr.	203	0	<35	......	39
South Creek	South of Beaver	0	71	0	<35	45	4
Seepage	Beaver	0	253	0	<35	......	55
Do	Sec. 21, T. 29 S., R. 7 W	0	263	0	68	......	247
Do	do	0	122	0	<35	......	25
Seepage (Sly, T. J.)	Sec. 29, T. 28 S., R. 6 W	0	240	0	<35	......	95
Seepage (Griffiths, T. M.)	Sec. 30, T. 29 S., R. 8 W	Tr.	410	0	<35	......	43
Do	Sec. 20, T. 29 S., R. 7 W	Tr.	240	0	<35	......	91
Do	Sec. 19, T. 29 S. R. 7 W	0	232	0	0	......	19

SPRINGS.

Laboratory analyses were made of the waters of three springs, as previously described (pp. 20, 21), and field assays were made of 15, as shown in Table 6. The same change in character found in the stream waters is seen also in the springs, the waters being purer in the upper parts of the valley than farther down. The average chlorine in the spring waters in the Beaver district is 19 parts per million, in the Greenville district 39, and in the two springs examined near Minersville a still greater amount. The alkalinity increases from 159 parts per million near Beaver to 191 near Greenville and much greater amounts at Minersville. This increase in salinity is evidently caused by the passage of the water through the sands and gravels of the Beaver Lake beds and by the leaching of the land through irrigation.

TABLE 6.—*Statistics of springs in Beaver Valley.*

[Chemical determinations in parts per million.]

District and owner	Location.	Flow per minute.	Temperature.	Iron (Fe).	Total alkalinity as $CaCO_3$.	Alkaline carbonates.	Sulphate radicle (SO_4).	Total hardness as $CaCO_3$.	Chlorine (Cl).	Remarks.
BEAVER DISTRICT.		*Gals.*	°*F*							
Baker, ———	Bakers Canyon		56	0	141	0	0	63	20	
Beaver Land and Livestock Co.	Sec. 9, T. 27 S., R. 8 W	7	48							
Do	Sec. 10, T. 27 S., R. 8 W	6	62							
Do	Sec. 4, T. 27 S., R. 8 W	6								
Boyter, A	Sec. 9, T. 29 S., R. 7 W	50		0	121	0	Tr.		5	
Cartwright, J. H	Sec. 21, T. 29 S., R. 7 W	22	52	0	162	0	Tr.		45	
Farnsworth & Bastian Bros.	Sec. 28, T. 28 S., R. 7 W	50	52							
Gale, O. W	Sec. 4, T. 29 S., R. 7 W	305		0	203	0	<35		15	Decreases three-fourths in winter.
Gale, Hannah	do	606								Decreases one-half by August 1.
Gillies, Geo. B	do	35	52							Maximum flow in June.
Gillies, D. M	do	332		0	172	0	<35		49	Minimum flow in August, one-third of maximum flow.
Greene, Henry	Sec. 36, T. 28 S., R. 7 W	112								Minimum flow in February, maximum in July.
Jackson, Jos	Sec. 28, T. 29 S., R. 7 W	164	54	0	182	0	0		15	Minimum flow one-fourth of maximum.
Mumford, Geo	do	180								
Owens, G. E	Sec. 27, T. 29 S., R. 7 W	270		0	253	0	0		34	Variation in volume one-third.
Parkinson, G. A	Sec. 22, T. 29 S., R. 7 W	250								
Patterson, Ed	Sec. 32, T. 29 S., R. 7 W	1		0	143	0	0		10	
Sly, T. J	Sec. 29, T. 28 S., R. 6 W	90		0	61	0	35	63	5	
Warby, Isaac	Sec. 35, T. 28 S., R. 7 W	256								Minimum flow in February, maximum in July.
White, C. D	Sec. 33, T. 28 S., R. 6 W	27	62							
Yardley, W. E	Sec. 21, T. 29 S., R. 7 W	103								Decreases one-third in winter.
GREENVILLE DISTRICT.										
Ashworth, H. H	Sec. 31, T. 29 S., R. 7 W	16		0	132	0	Tr.		20	
Farnsworth, P. T	do			0	134	0	Tr.		45	
Do	do			0	162	0	0		30	
Gillies & Bro	Sec. 11, T. 27 S., R. 8 W	7	52							
Green, Henry	Sec. 36, T. 28 S., R. 7 W	112								
Murdock, Chas. and J. M	Sec. 11, T. 27 S., R. 8 W	7		0	244	0	Tr.		45	
White, C. D	Sec. 31, T. 29 S., R. 7 W	12								Water brackish.

TABLE 6.—*Statistics of springs in Beaver Valley*—Continued.

[Chemical determinations in parts per million.]

District and owner.	Location.	Flow per minute.	Temperature.	Iron (Fe).	Total alkalinity as $CaCO_3$.	Alkaline carbonates.	Sulphate radicle (SO_4).	Total hardness as $CaCO_3$.	Chlorine (Cl).	Remarks.
MINERSVILLE DISTRICT.										
		Gals.	°*F*							
Dotson, R. W	Sec. 7, T. 30 S., R. 9 W	57	97	0	205	0	87	300	70	
Four miles north of Minersville.		50		0	243	0	<35	236	40	
Warm springs	Thermo		140	0	304	0	124		299	For exact analysis see Table 9 (p. 50).
McKean, P. B	T. 27 S., R. 9 W	10	210							Roosevelt Hot Spring. For exact analysis see Table 9 (p. 50).
Sulphur beds	Cove Creek									See description on p. 19.

DEEP WELLS.

Field assays were made of the waters of 36 deep wells. In general these show greater quantities of dissolved solids than the springs and shallow wells. The average chlorine in the deep wells near Beaver is 51 parts in a million parts of water, and the average alkalinity 251. For the Greenville region the average chlorine is 44 and the alkalinity 288, for the Adamsville region the average chlorine is 63 and the average alkalinity 255, for the Minersville region the average chlorine is 266 and the average alkalinity 328. A statement of averages in the Milford region would be misleading. The waters are very pure at Milford and very saline in Beaver Bottoms, where the chlorine content reaches a maximum of 1,787 parts per million. The chlorine occurs in these waters in the form of common salt (NaCl) and gives them a strong brackish taste. Exact analyses were made of the waters from two of the wells in the Milford district—the Milford town well and J. C. White's well at Beaver Bottoms. (See Table 9, p. 50).

SHALLOW WELLS.

Field assays of waters from the shallow wells are given in Table 4 (pp. 38–39). From this table it appears that the waters are variable in character and, like those of the streams, springs, and deep wells, increase in salinity toward the west, or away from the source of supply.

It is noteworthy in this connection that the samples were taken during a time when the water was high, in many places overflowing the wells. The salt content is therefore much less than it would have been at a time of low water. This is shown by the several assays made of water from J. F. Jones's well, in Beaver, given below. The water was flowing from the top of the well August 2, when the first sample was taken. August 24 it had fallen about 1 foot and no longer flowed from the well. September 11 the water surface was 6 feet below the top of the well. The figures here given are perhaps sufficient to show that during the lowest stage the water of some of the wells might be very unhealthful.

Field assays of water from J. F. Jones's well, Jones Hotel, Beaver.

[Parts per million. Analyst, Herman Harms.]

	Aug. 2.	Aug. 24.	Sept. 11.
Iron (Fe)	0	0	0.2
Total alkalinity as $CaCO_3$	243	273	----------
Alkaline carbonates	0	0	----------
Sulphate radicle (SO_4)	>35	>35	66
Chlorine (Cl)	65	80	99

BEAVER WELLS.

The variability in character of water in shallow wells is best illustrated by the wells of the town of Beaver, where samples were taken at no great distance apart and on the same day. Although a town of considerable size, Beaver has no water system and no sewers. The people depend for drinking water almost entirely on wells, most of them shallow and open. The town is the center of an agricultural district and according to the general custom in that part of the country, the ranchmen live in the town, driving their herds into the town at night and out of it to pasture in the morning.

Beaver is located in the center of the valley, where the land consists mainly of beds of unconsolidated gravel covered with scanty soil. There is little to prevent surface contamination from entering directly into the wells, and apparently the only reason for the water being in any measure fit for domestic use is that the open condition of the gravels allows the underflow to pass rapidly through them, thus keeping them in some degree cleansed and free from impurities which might otherwise produce serious consequences.

The contamination is strikingly shown by the assays given in Table 7. Several factors should be carefully considered in interpreting this table. The water samples were taken during the highest stage of the underground waters, a time when they contain the least quantity of saline matter. During the lower stages some of these same waters are reported unfit for use. The river water, which is the principal source of the underflow at Beaver, is very pure, as shown by the assay of water taken 4 miles upstream. This assay is placed at the head of Table 7 for comparison. The high chlorine content shown by most of the assays can not be ascribed to residual salt (NaCl) in the sediments of the Beaver Lake beds, in the case of the shallow wells, for the obvious reason that the river and irrigation waters flowing through them are less saline than that of the wells and tend continually to freshen the underground waters.

The only adequate explanation of the large quantities of the various salts in the well waters is that they are due to surface contamination. This explanation is confirmed by the variable amounts of chlorine shown by the assays. The chlorine is probably present in the form of common salt (NaCl) and is the element that shows surface contamination most clearly. The table is arranged to correspond with the map of Beaver (fig. 3), and the numbers in the first column correspond with the location numbers on the map. From an inspection of the table and map it appears that wells only a few rods apart vary greatly in the quantity of chlorine, the minimum amount being 18 and the maximum 303 parts in a million parts of water.

TABLE 7.—*Field assays of well waters in Beaver.*

[Parts per million.]

No. on fig. 3.	Owner.	Iron (Fe).	Total alkalinity as CaCO₃.	Alkaline carbonates.	Sulphate radicle (SO₄).	Chlorine (Cl).
	Beaver River, 4 miles east of Beaver	0	71	0	<35	9
1	Stony, F. J.	0	304	0	Tr.	18
2	Wolfenden, C.	0	344	0	<35	70
3	Smith, Seth W.	0	243	0	0	65
4	Okenden, C.	0	241	0	<35	308
5	Burt, Wm.	0	264	0	0	28
6	Muir, Jno. J.	0	245	0	<35	63
7	Farnsworth, W. H.	Tr.	233	0	<35	198
8	Owens, G. E.	0	253	0	0	35
9	Barrachouch, J.	2	253	0	<35	50
10	Harris, L. H.	Tr.	252	0	Tr.	28
11	Harris, Lydia	0	283	0	Tr.	60
12	Harris, H.	Tr.	182	0	<35	80
13	Brooks, John	0	263	0	<35	91
14	Atkins, Alice	0	281	0	<35	70
15	Morgan, Ed.	0	234	0	Tr.	33
16	Lawrence, A. L.	Tr.	250	0	<35	70
17	Swindelhurst, E. H.	0	242	0	Tr.	35
18	Wilden, E.	0	121	0	0	25
19	Robinson, Eliza	2	223	0	Tr.	40
20	Goodwin, I. S.	0	233	0	Tr.	51
21	Houd, S. F.	3	253	0	Tr.	47
22	Manhardt, W. M.	0	152	0	<35	24
23	Jones, J. F.	0	273	0	<35	80

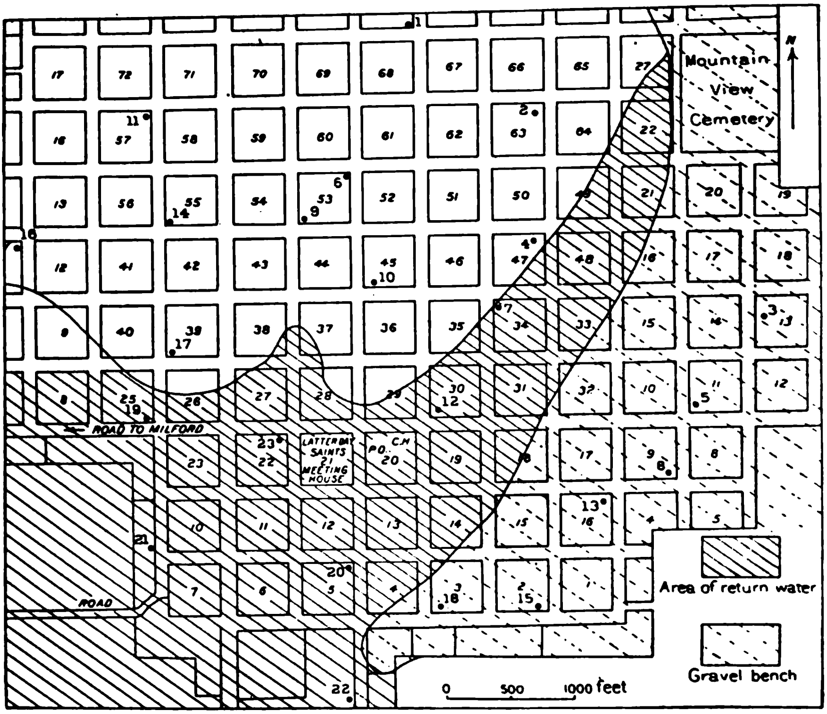


FIG. 3.—Map of Beaver, showing seepage area and location of wells included in Table 7.

SANITARY ANALYSES.

On account of the obviously unhealthful conditions affecting the waters of Beaver, four samples, taken September 1, 1906, were sent to Herman Harms, of Salt Lake City, State chemist of Utah, for sanitary analysis. The samples represent the principal sources of the water used for domestic purposes in Beaver. The results of Mr. Harms's analyses are given in Table 8. In commenting on them he unqualifiedly condemns the waters as unsuitable for domestic purposes.

TABLE 8.—*Sanitary analyses of Beaver waters.*

[Parts per million. Analyst, Herman Harms.]

	Canal at Stake Academy building.	Open well (Wm. Thomas, jr.).	Drilled well (J. F. Tolton).	Dug well (J. F. Jones, hotel).
Depth feet	Stream.	46	62	24
Odor	Faint.	Slight.	Faint.	Marked.
Odor on heating	Pronounced.	Pronounced.	Pronounced.	Decided.
Nitrates (diphenylamine reaction)	Trace.	Abundant traces.	Trace.	Abundant traces.
Nitrites (Greiss-Islosvay reaction):				
Cold	Faint.	Abundant.	Trace.	Abundant.
Heated to 175° F.	Trace.	Abundant.	Decided traces.	Abundant.
Hydrogen sulphide (H_2S)	0	0	0	0
Alkaline sulphides	0	0	0	0
Metallic impurities	0	0	0	0
Total dissolved solids at 212° F.	409	420	380	633
Calcium chloride ($CaCl_2$)	0	0	0	0
Magnesium chloride ($MgCl_2$)	0	0	0	0
Volatile matter	75	80	63	173
Mineral matter	354	339	317	459
Chlorine (Cl)	8	33	53	70
Common salt (NaCl)	13	55	87	115
Free ammonia	.03	.14	.05	.16
Albuminoid ammonia	.22	.19	.12	.35
Oxygen consumed	7.12	3.00	1.66	5.38

OTHER EXACT ANALYSES.

Six samples of water were sent to W. M. Barr, of the United States Geological Survey, for laboratory analysis. Three of these were from springs and three from wells. Of the springs one is acid water from the Cove Creek sulphur beds; one from Roosevelt Hot Spring, on the western slope of the Mineral Mountains, the waters of which are supposed to have valuable medical properties; and one from the group of warm springs near Thermo. The samples from the wells were selected to represent the shallow wells of the Beaver region (Jones's well), the artesian wells of the Milford district (Milford town well), and the artesian wells of Beaver Bottoms (J. C. White's well). The analyses are as follows:

TABLE 9.—*Laboratory analyses of water from Beaver Valley, Utah.*

[Parts per million. Analyst, W. M. Barr.]

Name.	Location.	Source.	Suspended matter.	Total dissolved solids at 180° C.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na, K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Nitric radicle (NO_3.)
McKean, P. B	Sec. 7 (?), T. 27 S., R. 9 W	Roosevelt Hot Spring	1,238	645	101	5	31	9.7	102	0	30	90	87	1.83
Milford	City	Flowing well	[a] 540	248	35	.1	11.2	6.6	66	0	190	53	13	.5
Jones, J. F	Hotel	Surface well	0	520	40	.2	106	29	43	0	276	66	99	1.7
Utah Sulphur Co.	Sulphurdale	Sulphur mine	52	10,810	124	1,362	158	232	144	0	0	7,602	79	1.7
(?)	Thermo	Warm springs	0	1,620	55	1.4	86	11	432	0	414	522	238	.0
White, J. C	Beaver Bottoms	Flowing well	0	2,937	24	0	133	127	727	0	495	35	1,570	.0

[a] The suspended matter is largely if not wholly due to the presence of fine sand drawn from the well by the pump. The well has recently been completed and the water-bearing beds had not been entirely cleared of loose sand when the sample was taken.

Several analyses of water used by the San Pedro, Los Angeles and Salt Lake Railroad have been made by Herman Harms, State chemist of Utah. The analyses were made with reference to the use of the waters for boiler purposes. The results are given by Mr. Harms, in grams per United States gallon, in the form of combined salts, but are here reduced to parts per million and to the ionic form in accordance with present usage of the United States Geological Survey.

TABLE 10.—*Analyses of waters from deep wells of San Pedro, Los Angeles and Salt Lake Railroad.*

[Chemical determinations in parts per million. Analyst, Herman Harms.]

Location.	Depth at which sample was taken.	Total dissolved solids.	Siliceous matter.	Undetermined and loss.	Ferric oxide (Fe_2O_3) and aluminum oxide (Al_2O_3).	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Carbonate radicle (CO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).
	Feet.										
Beryl	207	344	61	49	2	44	12	27	72	29	43
Lund (No. 1)	(?)	485	64	159	4	29	18	46	78	23	70
Lund (No. 2)	585	517	68	140	4	45	16	52	98	2	80
Thermo	401	689	161	244	10	32	15	57	84	4	87
Milford	305	330	90	137	8	47	10	8	51	0	12
Neels (No. 1)	1,382	3,336	48	544	14	284	3	298	20	658	a 1,065
Neels (No. 2)	1,398	3,345	370	488	13	197	15	691	36	472	1,063
Neels (No. 3)	1,974	2,888	39	586	10	289	6	552	25	458	b 863

a Samples taken after pumping 190 hours at 75 gallons per minute.
b Samples taken after pumping 38 hours.

POSSIBILITIES OF DEVELOPMENT.

SURFACE WATERS.

The surface waters used at the present time for irrigation in Beaver basin might, by proper manipulation, be made to serve a greatly increased acreage with no loss to the land now irrigated, and even, in the case of tracts that are being impaired by the use of too much water, with notable benefit to that land. The distribution of irrigation water at the present time is not under the supervision of any public official, and is wanting in adequate central control of any kind. An effort on the part of the community to bring about the passage and enforcement of some law providing for the equitable distribution of water would undoubtedly result in a great improvement of present conditions.

UNDERGROUND WATERS.

Drainage.—The conditions brought about by the behavior of the underground water in Beaver basin have become serious and are apparently growing worse year after year. According to report, the swampy areas caused by the midsummer rise of the water are increasing in size, and during the summer of 1906 roads and city streets that had never before been affected were rendered impassable, and dwellings that heretofore had been regarded as safe became uninhabitable.

An effort has been made by some of the citizens of Beaver, who realize the serious consequences to health likely to result from these conditions, to secure public action in draining the town or otherwise disposing of the superfluous water, but up to the time of the present writing nothing has been accomplished. The comparatively steep grade of the valley floor renders such drainage possible not only for the towns, but for much of the land which is now useless during the latter part of the summer. It is probable, however, that the water might be controlled more effectively and economically in other ways.

Pumping plants.—In many parts of the country where conditions similar to those of Beaver Valley prevail, pumping water for irrigation has proved more satisfactory in many ways than obtaining it by means of seepage ditches, and in view of the favorable conditions in Beaver basin it is probable that the establishment of a large number of pumping plants would not only serve the same purpose as expensive drainage systems in satisfactorily disposing of the overabundant underground water, but would render the water thus obtained more useful, since it could be better controlled and placed where it is most desired for irrigation.

The underground conditions in Beaver basin, so far as they are known, are very favorable for the operation of pumping plants, although no pumping experiments have ever been made there. The gravels are coarse and unconsolidated and the water moves through them with great readiness, as evidenced by the unusual yearly fluctuation of the water level within them. The lift would be small, since the water in summer reaches the surface of the ground over a large area. It is furthermore to be noted in this connection that the underground water reaches its maximum height during the summer—a fact especially favorable to the use of pumps, since the available quantity of water is greatest and the lift least during the time when the water is most needed for irrigation.

It should further be borne in mind that in the spring and early summer, when the maximum amount of water is carried by the streams, the underground water is moderately low. Later in the summer, when the streams are low, the underground waters attain their maximum volume. The increase in volume of the underground waters, although not coincident in time with the increase in volume of the streams, is primarily due to the increase in stream volume and secondarily to the use of the stream waters for irrigation. The lagging in effect is due to the obstruction offered by the sands and gravels to the passage of the water through them. The rain waters, irrigation waters, and stream waters enter the ground wherever it is porous enough to allow them to pass and gradually work their way down the valley, not in definite or well-defined underground channels, as is often believed, but as a general sheet saturating the sands and gravels of the valley filling. The coarser the material the faster will be the movement; hence there may be courses through the valley filling along which the water moves more rapidly than along others, but these can not be considered as underground channels. The water entering the valley filling at the upper end of the valley works its way slowly downward, as a general saturation of the sands and gravels, the maximum volume reaching a given point long after the time of maximum volume of the surface waters. Thus in Beaver basin the surface waters attain their maximum volume during May and June and the underground waters during July and August.

To judge from experience in other places where large quantities of water are pumped for irrigation, wells might be constructed in Beaver basin similar to those extensively used in southern California and in the Salt River Valley of Arizona,[a] with casing perforated from top to bottom, since the gravels are sufficiently coarse to act as strainers, and by means of centrifugal pumps such wells might be made to yield large quantities of water. It is within conservative limits to state that a single, properly constructed 12-inch well, 100 feet or less in depth, would easily yield 1,000 gallons of water per minute, a quantity more than sufficient to irrigate the average-sized ranch in Beaver Valley.

For the economic use of pumps for irrigation a convenient source of power is necessary. This is being provided for Beaver Valley. The Telluride Power Company has undertaken the construction of a large electric plant in Beaver Canyon, known locally as the Puffer Lake site, and the work of construction was begun during the autumn of 1906. The main object of the company is to produce power for use at the mines in the vicinity of Beaver Valley, but one of the transmission lines will pass through Beaver Basin, and power for pumping can probably be furnished at rates much cheaper than it can be produced in any other way.

Since no development of the underground waters of Beaver Basin has been effected, there is no information at hand by which their available quantity can be estimated, but to judge from the quantities pumped in Salt River Valley, Arizona, in southern California, and in other places where the underground conditions are similar to those in Beaver Basin, many hundreds of acres might be irrigated with pumped water in this valley. The writer is of the opinion that with the proper conservation and distribution of the surface waters, as previously suggested, and the development of the underground waters, the acreage of cultivated land in Beaver Valley might easily be doubled.

---

[a] Lee, W. T., Underground waters of Salt River valley, Arizona: Waters-Sup. and Irr. Paper No. 136, U. S. Geol. Survey, 1905.

Artesian conditions.—Water occurs under sufficient pressure in both the Beaver Lake and the Lake Bonneville beds to produce flowing wells. In the Beaver Lake beds the flow is probably due to the comparatively steep gradient of the surface of the underground water rather than to confinement of the water under impervious layers of rock. The sediments are apparently porous throughout and the underground water tends to return to the surface in the lowest parts of the valley. A well bored in the sediments furnishes an easier way of escape for the waters than the passage through the gravels. The slight pressure of the water in the flowing wells and the fact that only such wells flow as are located in or very close to areas where the underground water reaches the surface indicates the probable absence of any impervious layer that would tend to hold the waters in confinement. In other words, the Beaver Lake beds are not constituted in the manner commonly understood as necessary for the occurrence of artesian wells. The beds may rather be termed subartesian. Furthermore, the area in which flowing water is to be found is very small and nothing more is to be expected of the wells than to furnish a moderate supply of water for domestic purposes.

In the Lake Bonneville beds of the Escalante Desert, however, a different set of conditions prevail. Here the water is much less in volume than in the Beaver Lake beds, but the constitution of the sediments is such that the supply is better conserved. The Lake Bonneville beds are made up of alternating layers of sand, fine gravel, and clay. The sands and gravels are porous, allowing the water to work its way slowly through them, while the clay is impervious, thus retaining the water in confinement within the porous layers.

Much more is to be expected of flowing wells in the Escalante Desert than in Beaver Basin on account of the great volume of the Lake Bonneville beds. Although the small supply of water entering these beds is unfavorable to the occurrence of any great quantity of underground water within them, the great mass of the sediments and the fact that they are now saturated with water assures the permanence of the water supply for a long time to come. In the absence of experiments it is uncertain whether the underground waters could be obtained in sufficient quantity and at a cost sufficiently low to render them useful in irrigation; but it is reasonably certain that enough water for stock-raising purposes could be obtained throughout the Escalante Desert to make useful in this way a large territory that is now practically unproductive.

INDEX.

Page.
Acknowledgments to those aiding.......... 6
Adamsville district, wells in........ 25-26,35-36,39
Andesite, occurrence of.......... 11
Artesian conditions, existence of.......... 54
Aubrey limestone, occurrence of.......... 11
Aviculipecten occidentalis, occurrence of.... 10
  weberensis, occurrence of.......... 10
  sp., occurrence of.......... 10
Baker, Henry, well of.......... 36
Baker, H. F., well of.......... 36
Baker & Walker, well of.......... 26,36
  well of, record of.......... 27
Bakers Canyon, building stone in.......... 12
  spring in, analysis of.......... 44
Bakewellia sp., occurrence of.......... 10
Barr, W. M., analyses by.......... 6,42,49
Barton, J. H., well of.......... 23,35
  well of, record of.......... 23
Barton, S. R., well of.......... 35
Basalt, occurrence and description of.......... 12
Basin province, description of.......... 6-9
Beaver, map of.......... 48
  precipitation at.......... 15
  springs near.......... 19
  wells in and near.......... 23,36,47-49
    assays of.......... 48-49
Beaver Basin, location and character of.... 8, 14-15,41-42
  section across, figure showing.......... 14
Beaver Bottoms, location of.......... 8
  wells in.......... 30
Beaver Canyon, section in.......... 10-11
Beaver cemetery, well at.......... 23,35
  well at, record of.......... 23
Beaver district, springs of, analyses of..... 43,44
  wells of.......... 23-25,35,38-39
Beaver Lake beds, character of........ 8,13,40-41
  water in.......... 54
Beaver River, description of.......... 9
  flow of.......... 18
  irrigation from.......... 18
  water of, character of.......... 42-43
Beaver Valley, location and extent of...... 5
  location and extent of, map showing... 7
  map of.......... 5
Beryl, well at.......... 31,37
  well at, record of.......... 31
    water of, analysis of.......... 51
Black Mountain, rocks of.......... 12
Blackner, P., well of.......... 35
Blackrock, precipitation at.......... 15
Bonneville, Lake, location of.......... 7
  location of, map showing.......... 7

Page.
Boyter, A., well of.......... 40
  well of, record of.......... 40
Building stone, occurrence and description of.......... 11-12
Chemical data, sources of.......... 6
Colob Plateau, geology in.......... 11
Composita subtilita, occurrence of.......... 11
Cove Creek, spring on, analysis of....... 45,49-50
Deseret, precipitation at.......... 15
Deserts, description of.......... 6-8
Dotson, R. W., spring of.......... 21
  wells of.......... 36
Drainage, description of.......... 9,51-52
Edwards, William, well of.......... 35
Escalante Desert, description of.......... 12
  location of.......... 7-8
  underground water in.......... 54
  water on.......... 8-9
Farnsworth, G. T., well of.......... 35
Faults, occurrence and description of...... 13-14
Fillmore, precipitation at.......... 16
Fistulipora sp., occurrence of.......... 11
Forgie, James, well of.......... 36
Forgie, John, wells of.......... 36
Frisco, precipitation at.......... 15
Garrison, precipitation at.......... 15
Geography, description of.......... 6-9
Geology, description of.......... 9-15
Girty, G. H., fossils determined by.......... 11
Goodson, E. J., well of.......... 27,36
  well of, record of.......... 27
Grace Brothers, well of.......... 36
Granite, occurrence and description of..... 9-10
Greenville district, springs of, analyses of.. 43,44
  wells in.......... 25,35,39
Greenville school, well of.......... 25,35
  well of, record of.......... 25
Griffith, J. M., wells of.......... 25-26,35
  wells of, record of.......... 26
Grimshaw, F. T., well of.......... 36
Gum, F. T., well of.......... 36
Harms, Herman, analyses by.......... 6,42,49,51
Harrington, Mrs., well of.......... 36
Holderman & Sons, well of.......... 36
Hollingshead, S. B., well of.......... 36
Hot springs, cause of.......... 20-21
Hurricane fault, location and character of.. 14
Hustedia meekana, occurrence of.......... 11
Igneous rocks, occurrence and description of.......... 11-12
Indian Creek, flow of.......... 18
  irrigation from.......... 18
Irrigation, extent of.......... 18

Page.
Irrigation, pumping for 52-54
Johnson, Samuel, well of 26
Jones, J. F., well of, water of, assay of 46
Joseph, J. U., well of 26
Kelsey, W. M., well of 36
Lake Bonneville beds, occurrence and description of 12-13, 41
Lakes, prehistoric, occurrence and description of 7-8
Lakes, residual, occurrence and description of 8-9
Lewis, A. B., well of 28, 36
  well of, record of 28
Lund, well at 31, 37
  well at, record of 31
    water of, analysis of 51
Lynn, well at 34, 37
  well at, record of 34
McCauley, J. D., well of 37
McGregor, D. A., well of 35
McKean, P. B., springs of 20-21
  P. B., well of 37
Majestic Copper Mining & Smelting Co., wells of 30
Map of Beaver 48
  of Beaver Valley 5
  of Utah, showing location of area discussed 7
Marshall, George, well of 36
Meekella sp., occurrence of 11
Milford, wells at 27-30, 36, 37
  wells in, water of, analysis of 51
Milford district, wells in 27-30, 36-37
Milwaukee Leasing Co., well of 29, 37
Mineral Mountains, rocks of 9
Minersville, building stone near 12
  dam at 19
  irrigation at 9
  precipitation at 16
  rocks near 12
  section near 10-11
  spring near 21
  wells in and near 26-29, 36
Minersville district, springs of, assays of 43, 45
  wells in 26-27, 36, 39
Modena, precipitation at 16
Mowre, A. W., well of 37
Mumford, George, well of 24, 35
  well of, record of 24
Murdock, J. M., wells of 35, 37
Murdock, J. R., well of 35
Murdock, L. E., well of 36
Myalina peratenuata, occurrence of 10
Naticopsis sp., occurrence of 10
Neels, geology at 13
  well at 32, 37
    record of 33
    water of, analysis of 51-52
North Creek, flow of 18
  irrigation from 18
  water of, assays of 43
Nower, J. A., well of 24, 35
  well of, record of 24
Oasis, well at 33-34, 37
  well at, record of 34
Paleozoic sediments, description of 10-11

Page.
Parkinson, Earl, well of 26, 35
  well of, record of 26
Parowan, precipitation at 16-17
Parowan Valley, location and character of 8, 13, 14
Pioche, Nev. precipitation at 17
Piute, precipitation at 17
Plateau province, description of 6
Pleurophorus sp., occurrence of 10
Pleurotomaria sp., occurrence of 10
Power, supply of 53
Precipitation, records of 15-17
Productus subhorrida, occurrence of 11
Pugnax osagensis, occurrence of 11
Pumping for irrigation, advantage of 52-54
Railroad wells, location of 29, 30-34
  records of 29, 30-34
Rhyolite, occurrence and description of 11-12
Roosevelt Hot Spring, location and description of 20-21
  water of, assay of 49-50
Rush Lake Valley, location of 8, 13
Ryan ranch, well on 37
San Pedro, Los Angeles and Salt Lake River, wells of 31-34, 37
  wells of, records of 31-34
Schizodus sp., occurrence of 10
Seepage waters, assays of 43
  location and volume of 22
Setopora sp., occurrence of 11
Shepherd, Warren, well of 24, 35
  well of, record of 24
South Creek, flow of 18
  irrigation from 18
  water of, assay of 43
Spirifer cameratus, occurrence of 11
Spiriferina Kentuckyensis, occurrence of 11
  sp., occurrence of 11
Springs, occurrence and description of 19-22
  waters of, assays and analyses of 43-45
Squamularia perplexa, occurrence of 11
  sp., occurrence of 11
Stratigraphy, description of 9-13
Structure, description of 13-15
  diagram showing 14
Sulphurdale, springs at 19
  springs at, water of, analysis of 20
Surface waters. *See* Waters, surface.
Swamps, occurrence of 22, 41-42
Tanner, Caleb, aid of 6
Tanner, E., wells of 37
Thermo, warm springs near 21-22
  warm springs near, analyses of 45, 49-50
  well at 32, 37
    record of 32
    water of, analysis of 51
Tolton, J. F., well of 35
Tuskar Mountains, rocks of 10, 11, 14
  water from 17
Underground waters, description of 19-54
Utah, cooperation of 6
Van Patten, F. A., well of 27, 36
  well of, record of 27
Walker, H. A., well of 36
Water-bearing beds, description of 40-41
Water level, changes in 41-42
Water supply, assays and analyses of 43-51

	Page.
Water supply, chemical character of	43-51
chemical character of, determination of.	42
development of	51-54
discussion of	15-54
Waters, surface, chemical character of	42-45
development of	51
Waters, underground, description of	19-54
development of	51-54
supply of	53-54
Wells, deep, classification of	23
descriptions of	23-34
statistics of	34-37
Wells, deep, waters of, assays of	46
Wells, shallow, statistics of	37-38
waters of, assays of	46
Whitaker, Arthur, well of	37
White, J. C., information from	30, 37
Winberg, A. W., well of	28, 37
well of, record of	29
Wolfenden & Murdock, well of	25
well of, record of	25
Xenodiscus sp., occurrence of	10
Zaphrentis sp., occurrence of	11

O

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 218

WATER-SUPPLY INVESTIGATIONS IN ALASKA, 1906-1907

NOME AND KOUGAROK REGIONS, SEWARD PENINSULA; FAIRBANKS DISTRICT, YUKON-TANANA REGION

BY

FRED F. HENSHAW AND C. C. COVERT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1908

CONTENTS.

Page.
Introduction........ 7
  Scope of work........ 7
  Cooperation........ 8
  Explanation of data and methods........ 9
The Nome region, by Fred F. Henshaw........ 13
  Description of area........ 13
  Conditions affecting water supply........ 15
  Gaging stations........ 18
  Nome River drainage basin........ 18
    General description........ 18
    Nome River above Miocene intake........ 19
    Nome River at Pioneer intake and Pioneer ditch........ 21
    Buffalo Creek........ 22
    David Creek........ 22
    Dorothy Creek........ 23
    Hobson Creek........ 23
    The Miocene ditch system........ 24
      General description........ 24
      Jett Creek ditch........ 30
      Grand Central ditch........ 31
      David Creek ditch........ 32
      Seepage measurements on Miocene ditch........ 33
      Miscellaneous measurements........ 35
    Campion ditch at Black Point........ 35
    Seward ditch........ 36
    Pioneer ditch........ 37
  Grand Central River drainage basin........ 38
    General description........ 38
    North Fork of Grand Central River........ 38
    West Fork of Grand Central River........ 41
    Crater Lake outlet........ 44
    Grand Central River below the forks........ 46
    Grand Central River below Nugget Creek........ 47
    Gold Run........ 48
    Thompson Creek........ 49
    Nugget and Copper creeks........ 49
    Jett Creek........ 50
    Morning Call Creek........ 51
    Storage possibilities........ 52
  Salmon Lake........ 53
  Kruzgamepa River drainage basin below Salmon Lake........ 54
    General description........ 54
    Kruzgamepa River at outlet of Salmon Lake........ 55
    Crater Creek........ 57
    Iron Creek........ 57
    Miscellaneous measurements........ 59
  Imuruk Basin drainage........ 59

The Nome region—Continued.

Page.
- Sinuk River drainage basin 60
  - General description 60
  - Upper Sinuk River 60
  - Windy Creek 61
  - North Star Creek 62
  - Stewart River 63
  - Slate Creek 63
  - Other Sinuk River drainage 64
- Cripple River drainage basin 64
  - General description 64
  - Cedric ditch 64
    - General description 64
    - Cedric ditch above penstock 65
- Penny River drainage basin 66
  - General description 66
  - Penny River at Sutton intake and Sutton ditch 66
- Snake River drainage basin 68
  - General description 68
  - Snake River above Glacier Creek 68
- Flambeau and Eldorado River drainage basins 69
- Solomon River drainage basin 69
- Flow of ditches in Nome region 70
- Available water supply during 1906 and 1907 70
- Ditch and pipe lines 72
- Water-power possibilities 76

The Kougarok region, by Fred F. Henshaw 77
- Introduction 77
- Description of area 77
- Conditions affecting water supply 78
- Gaging stations 79
- Kougarok River drainage basin 79
  - Description of basin 79
  - Kougarok River below Washington Creek 80
  - Kougarok River at Homestake intake and Homestake ditch 80
  - Kougarok River above Taylor Creek 82
  - Kougarok River above Coarse Gold Creek 82
  - Irving ditch 83
  - Homestake ditch 83
  - Taylor Creek at North Star intake 84
  - Taylor Creek at Cascade intake 85
  - Taylor Creek at mouth 86
  - North Star ditch above siphon 86
  - Cascade ditch 87
  - Henry Creek 88
  - Coarse Gold Creek 88
  - North Fork 89
  - Miscellaneous measurements 90
  - Total water supply in 1907 90
- Noxapaga River drainage basin 91
- Serpentine River drainage basin 92
  - Schlitz and Reindeer creeks 92
  - Bryan and Dick creeks 92
  - Quartz and Bismarck creeks 93
- American River drainage basin 93

The Kougarok region—Continued. Page.
- Hydraulic developments 94
- Relative run-off of different areas 95

The Fairhaven precinct, by Fred F. Henshaw 99
- Introduction 99
- Fairhaven ditch 99
- Candle ditch 100
- Bear Creek ditch 100

The Fairbanks district, by C. C. Covert 101
- Description of area 101
- Conditions affecting water supply 103
- Gaging stations 106
- Little Chena River drainage basin 106
  - General description 106
  - Chena Slough at Fairbanks 108
  - Little Chena River above mouth of Elliott Creek 109
  - Elliott Creek above mouth of Sorrels Creek 110
  - Sorrels Creek 110
  - Fish Creek above mouth of Fairbanks Creek 111
  - Bear Creek 112
  - Fairbanks Creek 112
  - Miller Creek 113
- Chatanika River drainage basin 114
  - General description 114
  - Faith Creek 115
  - McManus Creek 116
  - Chatanika River near junction of Faith and McManus creeks 117
  - Boston Creek 118
  - McKay Creek 119
  - Belle Creek 119
  - Crooked Creek 119
  - Kokomo Creek 119
  - Poker Creek 120
  - Chatanika River below mouth of Poker Creek 121
  - Cleary Creek 122
  - Little Eldorado Creek 122
  - Dome Creek 122
- Goldstream Creek drainage basin 123
  - General description 123
  - Goldstream Creek at claim 6 below 124
  - Fox Creek 125
- Beaver Creek drainage basin 125
  - General description 125
  - Measurements 127
- Comparative run-off of different areas 128
- Development of water supply in the Fairbanks district 129
  - General conditions 129
  - Ditch lines 130
  - Water-power development 131
  - Storage 131

Meteorological records, by Fred F. Henshaw and C. C. Covert 133
- Introduction 133
- Seward Peninsula 134
- Fairbanks district 139
- Summary of records since 1902 142

Index 151

ILLUSTRATIONS.

Page.
PLATE I. *A*, Price current meters; *B*, Measuring Grand Central River......... 10
II. Typical topography, Seward Peninsula.............................. 14
III. *A*, Tundra between beach and foothills; *B*, Miocene ditch, Glacier Creek.. 16
IV. Map showing location of gaging stations in Nome region............. 18
V. Rock cut around Cape Horn on Miocene ditch....................... 24
VI. *A*, Upper Grand Central River drainage; *B*, Mount Osborn, July, 1906 38
VII. Map showing location of gaging stations and ditches in Kougarok region... 78
VIII. *A*, Intake of Homestake ditch on Kougarok River; *B*, Homestake ditch, showing sod work.................................. 80
IX. Map showing location of gaging stations in Fairbanks district........ 106
X. Mining operations on Cleary Creek................................ 122
XI. *A*, Lower Cleary Creek; *B*, Gaging station on Fish Creek............ 124
XII. Map of Alaska, showing location of rainfall stations.................. 142
FIG. 1. Diagram showing flow of Nome River above Miocene intake and Grand Central River below the forks, 1906......................... 17
2. Diagram showing flow of Chatanika River and total of Little Chena River and its tributaries, 1907.................................. 105

WATER-SUPPLY INVESTIGATIONS IN ALASKA, 1906-1907.

By Fred F. Henshaw and C. C. Covert.

INTRODUCTION.

SCOPE OF WORK.

For a number of years the United States Geological Survey has made systematic measurements and studies of the water supply as one of the great resources of the country. These data are now available for all the more important streams in the United States and are extensively used by engineers and others in problems involving water power, city water supply, irrigation, and manufacturing.

The development of the important placer-mining fields of Alaska, notably those of Seward Peninsula and the Yukon-Tanana region, is intimately associated with the successful utilization of their water supplies. A knowledge of the amount of water available in the streams would have prevented most of the failures that have been made in the past, and will be invaluable in connection with future developments.

There is a great tendency in Alaska to push forward the construction of ditches without first making sure of the primary requisite of their successful operation—an adequate water supply. The results of such a policy were forcibly shown during last summer in Seward Peninsula, in some parts of which a severe drought caused much loss and inconvenience to mining operators. These conditions are apt to occur in any portion of Alaska, and too much stress can not be laid on the importance of stream-flow data. The low-water period lasts only a part of the season and the water supply is usually sufficient at other times, but in view of the other unfavorable conditions—the shortness of the season, the frozen ground, the distance from base of supplies and consequent high cost of transportation—a reduction of even two or three weeks in the working season may mean the difference between profit and loss. The cost of the useless machinery and ditches which can be seen in some parts of Alaska amounts to hundreds of thousands of dollars, and most of this could have been saved by a preliminary investigation of conditions by a competent engineer.

Hydraulic developments have been carried farthest in the Nome region of Seward Peninsula, which has been an important producer of placer gold since 1899. Hundreds of miles of mining ditches have been built at a great expense. When it was decided in 1906 to extend stream-gaging work to Alaska, the Nome region was accordingly selected as the first district to be studied. A reconnaissance was made and gaging stations were established by John C. Hoyt in the early summer of 1906, and the work was then carried on until the end of the season by Fred F. Henshaw. During last season the work was continued by Mr. Henshaw, assisted by Raymond Richards, and was extended into the Kougarok region, north of the Kigluaik Mountains, in the central portion of Seward Peninsula. Altogether the parties were in Seward Peninsula from June 11 to October 3, 1906, and from June 11 to October 14, 1907.

The collection of stream-flow records was begun in the Fairbanks district of the Yukon-Tanana region by C. C. Covert in 1907. The work was largely that of reconnaissance, but a few regular stations were established.

The work of collecting the data and preparing this report was done under the direction of the water resources branch by engineers detailed for the purpose. The expenses were paid out of the appropriation for investigating the mineral resources of Alaska, and the field work has been under the general supervision of Alfred H. Brooks, geologist in charge of Alaskan work.

COOPERATION.

The funds available for the work were inadequate to cover properly the large extent of country on which it was desirable to obtain records. It was possible to obtain daily gage readings only through the hearty cooperation of mining operators, ditch companies, and others. Those to whom special acknowledgment is due are named below:

In the Nome region, to the officers and employees of the Miocene Ditch Company, Wild Goose Mining and Trading Company, Cedric Ditch Company, Pioneer Mining Company, Gold Beach Development Company, and the United Ditch Company; to W. L. Leland, of the Three Friends Mining Company; to J. E. Styers, superintendent of construction for the National Wood Pipe Company; and to Arthur Gibson, George Ashley, William E. Morris, J. Potter Whittren, Mark N. Alling, and George M. Ashford, civil and mining engineers, Nome.

In the Kougarok region, to the officers and employees of the Kougarok Mining and Ditch Company, Taylor Creek Ditch Company, Pittsburg-Dick Creek Mining Company, Irving Mining Company, Cascade Mining and Ditch Company, Ottumwa Gold Mining Company, and to others for information and accommodations in camp.

In the Fairbanks district, to John Zug, superintendent good roads commission; A. D. Gassaway, general manager of the Chatanika Ditch Company; Falcon Joslin, president of the Tanana Mines Railroad Company; Herman Wobber, Fairbanks Creek; C. D. Hutchinson, electrical engineer, Tanana Electric Company, and Martin Harris, Chena.

EXPLANATION OF DATA AND METHODS.

The methods of carrying on the work and collecting the data were substantially the same as those previously used for similar work,[a] but were adapted to the special conditions found in Seward Peninsula.

In the consideration of industrial or mining enterprises which use the water of streams, it is essential to know the total amount of the water flowing in the stream, the daily distribution of the flow, and facts in regard to the conditions affecting the flow. Several terms are used, such as second-foot, miner's inch, gallons per minute, etc., to describe the quantity of water flowing in a stream, the one selected depending on the use to be made of the data.

"Second-foot" is in most general use for all classes of work, and from it the quantity expressed in other terms may be obtained. It is an abbreviation of cubic foot per second and may be defined as the quantity of water flowing per second in a stream 1 foot wide and 1 foot deep at the rate of 1 foot per second. It should be noted that it is a rate of flow, and to obtain the actual quantity of water it is necessary to multiply it by the time.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly, as regards both time and area.

"Run-off in inches" is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is expressed in depth in inches.

"Acre-foot" is equivalent to 43,560 cubic feet, and is the quantity required to cover an acre to the depth of 1 foot. It is commonly used in connection with storage problems.

The "miner's inch," the unit used in connection with placer mining, also expresses a rate of flow, and is the quantity of water flowing through an orifice of a given size, with a given head. The head and size of the orifice used in different localities vary, thus making it a most indefinite and unsatisfactory unit. Owing to the confusion arising from its use, it has been defined by law in several States. The California miner's inch is in most common use in the United States and was defined by an act approved March 23, 1901, as follows: "The standard miner's inch of water shall be equivalent or equal to 1½ cubic feet of water per minute, measured through any aperture or orifice." This miner's inch corresponds to the so-called "6-inch pressure" and is one-fortieth of a second-foot. The inch in most common use in Seward Peninsula is the "old California inch," which was the standard in that State prior to the passage of the above act and is equivalent to 1.2 cubic feet per minute, or one-fiftieth of a second-foot.

---

[a] See Water-Sup. and Irr. Papers Nos. 94, 95, and 201, U. S. Geol. Survey.

Following is a list of convenient equivalents for use in hydraulic computations:

1 second-foot equals 40 California miner's inches (law of March 23, 1901).

1 second-foot equals 50 "old California" miner's inches (used prior to law of March 23, 1901).

1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,272 gallons for one day.

1 second-foot for one year covers 1 square mile 1.131 feet, or 13.572 inches deep.

1 second-foot equals about 1 acre-inch per hour.

1 second-foot for one day covers 1 square mile 0.03719 inch deep.

1 second-foot for one day equals 1.983 acre-feet.

100 California miner's inches equal 15.7 United States gallons per second.

100 California miner's inches for one day equal 4.96 acre-feet.

100 United States gallons per minute equal 0.223 second-foot.

100 United States gallons per minute for one day equal 0.442 acre-foot.

1,000,000 United States gallons per day equal 1.55 second-feet.

1,000,000 United States gallons equal 3.07 acre-feet.

1,000,000 cubic feet equal 22.95 acre-feet.

1 acre-foot equals 325,850 gallons.

1 inch deep on 1 square mile equals 2,323,200 cubic feet.

1 inch deep on 1 square mile equals 0.0737 second-foot per year.

1 mile equals 5,280 feet.

1 acre equals 43,560 square feet.

1 acre equals 209 feet square, nearly.

1 cubic foot equals 7.48 gallons.

1 cubic foot of water weighs 62.5 pounds.

1 horsepower equals 550 foot-pounds per second.

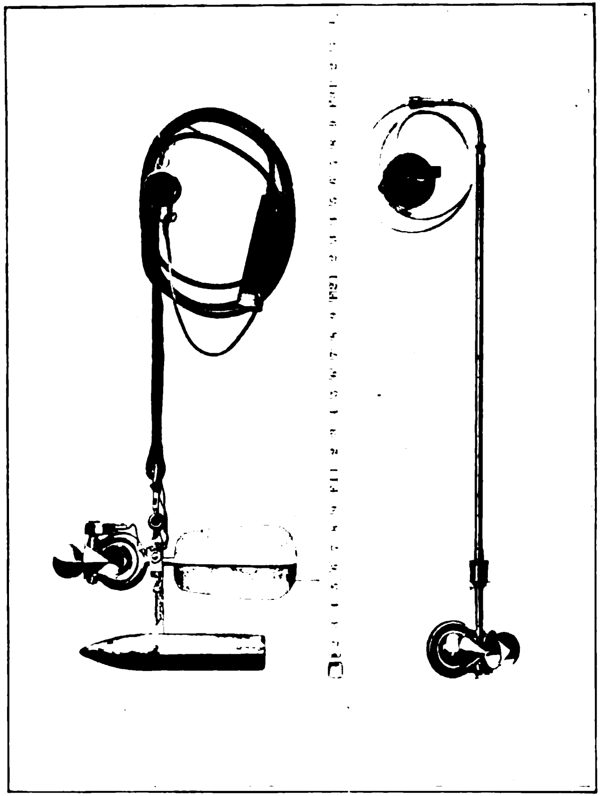
1 horsepower equals 746 watts.

1 horsepower equals 1 second-foot falling 8.80 feet.

1⅓ horsepower equal about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Sec. ft.} \times \text{fall in feet}}{11}$ = net horsepower on waterwheel realizing 80 per cent of theoretical power.

The determination of the quantity of water flowing past a certain section of a stream at a given time is termed a discharge measurement. The quantity is the product of two factors—the mean velocity and the area of the cross section. The mean velocity is a function of surface slope, wetted perimeter, roughness of bed, and the channel conditions at, above, and below the gaging section. The area depends on the contour of the bed and the fluctuations of the



A. PRICE CURRENT METERS.

B. MEASURING GRAND CENTRAL RIVER.

surface. The two principal ways of measuring the velocity of a stream are by floats and current meters.

All current-meter measurements are made by the engineers of the Survey, but as float measurements can readily be made by the prospector the method is described below.

The floats in common use are the surface, subsurface, and tube or rod floats. A corked bottle with a flag in the top and weighted at the bottom makes one of the most satisfactory surface floats, as it is affected but little by wind. In flood measurements, good results can be obtained by observing the velocity of floating cakes of ice or débris. In all surface-float measurements the observed velocity must be multiplied by 0.85 to 0.90 to reduce the surface velocity to the mean velocity. The subsurface and tube or rod floats are intended to give directly the mean velocity in the vertical. Tubes give excellent results when the channel conditions are good, as in canals.

In measuring velocity by a float, observation is made of the time taken by the float to pass over the "run"—a selected stretch of river from 50 to 200 feet long. In each discharge measurement a large number of velocity determinations are made at different points across the stream, and from these observations the mean velocity for the whole section is determined.

The area used in float measurements is the mean of the areas at the two ends of the run and at several intermediate sections.

The essential parts of the current meters in use are (1) a wheel of some type so constructed that the impact of flowing water causes it to revolve and (2) a device for recording or indicating the number of revolutions. The relation between the velocity of the moving water and the revolutions of the wheel is determined for each meter. This rating is done by drawing the meter through still water for a given distance at different speeds and noting the number of revolutions for each run. From these data a rating table is prepared which gives the velocity per second for any number of revolutions. Many kinds of current meters have been constructed.

The small Price acoustic meter (see Pl. I, *A*) was used exclusively in the work in Alaska. Measurements were made by wading, except on Kruzgamepa River, where a cable and car were installed for use during high stages.

In making a measurement a tape line is stretched across the stream (see Pl. I, *B*) and depth and velocity are measured at regular intervals (from 1 to 5 feet apart, depending on the size of the stream). The depths from which the area of the cross section is computed are taken by soundings with a graduated rod. The velocities are measured by a current meter.

Three methods of measuring the velocity were used. In the first the meter is held at the depth of the thread of mean velocity, which has been shown by extensive experiments to occur at about 0.6 of the total depth. In the second method the mean of the velocities taken at 0.2 and 0.8 depth is taken as the mean. In the third method the meter is held at mid depth and about 0.1 of the total depth below the surface and above the bottom, and one-fourth of the sum of the top and bottom and twice the mid depth is used as the mean. This method is not adapted to very shallow streams or to those with extremely rough beds.

One of the general laws of the flow of streams with permanent cross sections is that the discharge varies directly with the stage, or gage height, and that it will be the same whenever the stage or gage height of the stream is the same. Therefore, in order to determine the daily discharge of a stream, a gage on which the fluctuations of the surface of the stream may be noted is installed and read daily. As the discharge regularly increases with the stage, it is possible with a few discharge measurements taken at various stages to construct a rating curve which will give the discharge at all stages. The beds of most of the streams measured changed but little during the season and it was therefore possible to obtain the daily flow as just stated.

Water to be of use for mining purposes must be available under considerable pressure, or when diversion is necessary it must be taken at an elevation high enough to allow it to be carried over the divides. The gaging stations, therefore, were so established as to obtain measurements at points whose elevations were sufficient to permit the stream to be diverted for use in mining on the ground already prospected. Such stations were established on all the important streams in the area. At some of the locations it was impossible to secure gage readers to take the daily observations of river height, and for these stations, therefore, it is possible only to give the flow at the time of the actual discharge measurements.

THE NOME REGION.

By Fred F. Henshaw.

DESCRIPTION OF AREA.

The area to which the term "Nome region" is applied is, in a general way, 15 to 20 miles wide and stretches 40 miles inland from the town of Nome, which is situated on the southern coast of Seward Peninsula. Most of the measurements recorded in this paper were made about 20 to 25 miles from the coast, at points where the altitude is sufficiently high to make the water available for mining high-level placers, but some trips were also made into the adjacent regions to the east and west.

The region embraces three types of topography, which, from south to north, are (1) a coastal plain, (2) an upland, and (3) a mountain mass.

Bordering the coast line between Cape Nome and Cape Rodney is an area of low relief, which stretches back to the foothills with a width of 2 to 5 miles. This lowland, known as the "Nome tundra," is made up in general of wet, moss-covered ground, rising with a gentle slope to an elevation between 200 and 300 feet at the southern margin of the upland.

The ridges that constitute the upland trend in a general way north and south, rising from about 700 feet near the coast to 2,000 feet 30 miles inland. These ridges are separated by the broad U-shaped valleys of the larger drainage courses. Thirty miles from the coast the ridges are united by an east-west ridge, which presents a steep escarpment toward a broad depression to the north. This depression separates the upland from the Kigluaik Mountains.

The east-west ridge is broken by broad, low gaps, a feature of great importance to the engineer who contemplates tapping the water resources of the Kigluaik Mountains. North of the depression the Kigluaik Mountains, locally known as the Sawtooth Range, rise abruptly, constituting a rugged east-west mass, sharply dissected, with serrated crest line. As these mountains have been the center of local glaciation in recent times, their valleys are characterized by cirques, which form important sources of water for the district.

Most of the area here considered drains southward to Bering Sea through Nome and Snake rivers, whose sources lie close to the ridge which forms the northern boundary of the upland. A part of the waters of the upland also flows southward to Bering Sea through Eldorado, Flambeau, Cripple, and Penny rivers. The valleys of all of these streams are of about the same type—broad and deep in the upland, with gentle slopes for 300 to 600 feet, then with steeper walls which rise to crest lines ranging from 800 to 1,500 feet in altitude. Their floors are usually covered with gravels. Some of the smaller tributaries occupy sharply incised trenches and have but a thin coating of gravel on their rock floors.

The east-west depression which separates the upland from the mountains to the north is drained in part by streams flowing westward to Sinuk River, which empties into Bering Sea, and in part by streams flowing eastward to Kruzgamepa River, which discharges into Imuruk Basin. The streams draining the southern slope of the Kigluaik Mountains are all tributary to one or the other of the two systems. Many of them head in glacial cirques and flow through steep-walled rock-bound valleys, and all have torrential courses.

The general character of all the drainage areas is the same. (See Pl. II.) The streams have little slope, except in their extreme upper portions, and spread over wide gravelly beds, in which many of them divide into several channels or disappear in the gravel. The channels are also subject to considerable shifting during floods. For 1,000 to 3,000 feet on either side of this gravelly bed extend level or gently sloping bottom lands, from which the hills rise abruptly. The drainage basins are from 4 to 12 miles wide. Most of the tributary streams are short and flow in narrow ravines having steep sides. Their slope is great, and many of them are made up of a series of rapids, waterfalls, and pools.

Practically the whole country to an elevation of 1,000 feet is covered with a thick turf, commonly known as "tundra." (See Pl. III, *A*.) In the summer this turf carries a rank growth of grass dotted with wild flowers of many varieties, and in some areas there is considerable moss. There are no trees with the exception of scattered patches of scrub willow and alder, which in the absence of better fuel can be used for firewood. Much of the ground remains frozen within 2 feet of the surface throughout the year. The soil in the lowlands is mostly gravel, overlain with muck, which contains a large percentage of water, and, when it thaws out in summer, becomes very soft. Considerable areas are underlain by clear ice. The hills are composed largely of schist and limestone rock, mantled with loose slide and gravel.

The Nome region has been an important producer of placer gold since 1899. During the first two or three years operations were confined largely to the shallower and richer creeks and to the present beach. They were carried on by the primitive methods of rocking and shoveling in, and the producing creeks themselves usually furnished an adequate sluice head.

During the last five or six seasons the operations have been of two widely different kinds, namely, underground and hydraulic mining.

The ancient beaches, notably the so-called third beach, have yielded the largest production during the last four years. The work is carried on underground, by shaft and drift, largely in the winter, the material being sluiced with water derived from the melting snow in the spring. Owing to the small yardage moved and the high tenor of the gravels, the problem of obtaining a water supply for sluicing is relatively unimportant. Pumping by gasoline engine is often resorted to and does not materially increase the total cost of mining. In hydraulic mining the conditions are radically different. The chief requirements are a large body of gravel carrying values and an abundant supply of water under a high head.

The stream-gaging work of the Survey in this district has been carried on for the purpose of obtaining accurate information in regard to its water resources, developed and undeveloped, and their adaptation both for placer mining and power. Most of the work in the Nome region in 1907 was done by Raymond Richards, and much credit is due him for the careful and thorough manner in which he carried it on.

The work has been confined to the comparatively small area from which water has been or can be diverted for working the rich placer deposits near Nome. The gaging stations were so located that the measurements would show the water available in this important area. The additional water supply below the points of measurement may on many streams have a local value, and all the streams in the vicinity of the gold-bearing ground of Seward Peninsula are of more or less economic importance, but it was impossible to measure them all on account of inadequate funds.

The results obtained in 1906 have been published, but are included in this report in order to bring all the records up to date.[a]

The data obtained give a fair idea of conditions of flow that may be expected from other areas in the vicinity, provided allowance is made for difference in rainfall, topography, and soil. For this purpose a summary of the flow from different areas has been prepared. (See p. 95.)

CONDITIONS AFFECTING WATER SUPPLY.

Three sources of water supply contribute to the run-off of Seward Peninsula—summer rains, melting of accumulated snow, and melting of the frozen ground.

Comparatively few data concerning the rainfall are available for years prior to 1906, when rainfall records were begun by the Geological Survey in connection with the investigations of stream flow.

---

[a] Hoyt, J. C., and Henshaw, F. F., Water supply of Nome region, Seward Peninsula, 1906: Water-Supply and Irrigation Paper No. 196, U. S. Geological Survey. The edition of this paper is completely exhausted.

Records were received from three stations in 1906 and from six in 1907. The daily and monthly rainfall at these points is given on pages 136 to 138.

In the opinion of the mining operators at Nome, the season of 1907 was one of the best for water supply since the settlement of the region, whereas 1906 was about the poorest. An examination of the tables of rainfall will reveal the fact that this difference must have been due less to the greater total rainfall of 1907 than to its more even distribution through the season. A brief statement of climatic conditions for the last nine years is given on page 135.

At Salmon Lake the total rainfall from June to September was greater in 1906 than in 1907 by nearly 2 inches, but as almost half of the total fell in six days during the heavy storms of July 8 to 10 and September 19 to 21, the minimum flow was smaller and lasted longer than in 1907.

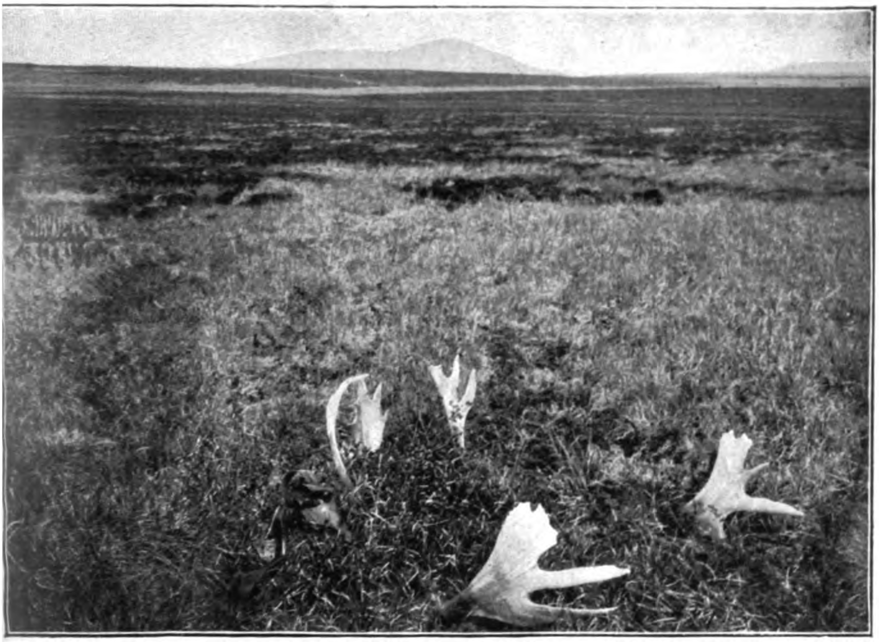
The record of snowfall for the winter of 1906–7 at Nome is the only one available. The total (88.7 inches) was abnormally high, and was perhaps double that of some other years. The snowfall in the Kigluaik Mountains is probably much larger than that on the coast.

In 1906 most of the snow in this region had melted before the 1st of June. Only the drifts in the gulches and along the north sides of the hills and the ice banks along the beds of the rivers remained after the 15th. The spring of 1907 was much later and the snowfall of the previous winter was heavier. On June 15 the ground in the mountains was still largely covered with snow, and the daily fluctuation of Nome River, due to the more rapid melting of the snow in the daytime, continued until about July 20.

With the exception of Sinuk and Nome rivers, which have their sources in the mountains a short distance apart, the streams flowing into Bering Sea rise in the foothills of the Kigluaik Range. Their drainage areas have a southern exposure and the snow on them melts early in the season. They are, therefore, dependent for their water supply mostly on the summer rains. The cirques in the Kigluaik Mountains are more protected and hold their snow later in the season, so that the flow of the streams which rise in them is much better sustained.

Some water finds its way into the streams from the melting of the frozen ground. The frozen muck and ground ice, which carry a large amount of water, are protected with a thick coating of moss, through which the heat of summer hardly penetrates, and therefore they thaw very little. The gravelly and sandy soils, which often thaw to a considerable depth, contain much less water. This source of water supply is of minor importance.

In the Nome region there is much ground which becomes thawed and takes up the rain as ground storage, especially late in the season.



A. TUNDRA BETWEEN BEACH AND FOOTHILLS.

B. MIOCENE DITCH AT GLACIER CREEK.

The coming of the frosts, however, checks the flow of the ground water.

Owing to the steep slopes, the thinness of the surface covering, and the shallow depth to which the ground thaws, the water from the rains finds its way into the streams in a very short time, and the streams rise and fall very rapidly. (See fig. 1.) During the heavy storm of July 8, 1906, it was noted that although all supply gates of the Miocene ditch were closed and the waste gates were open, the ditch was running full from the rain water coming in from the slopes above. Owing to this lack of ground storage, which is one of the important factors in maintaining a well-sustained stream flow in warmer climates, the streams depend in great part on the rainfall and melting snow for their supply and respond very quickly to an increase or decrease in either. If two or three weeks pass with hardly any rain, as during the last week in July and the first half of August in both 1906 and 1907, the streams will fall rapidly.

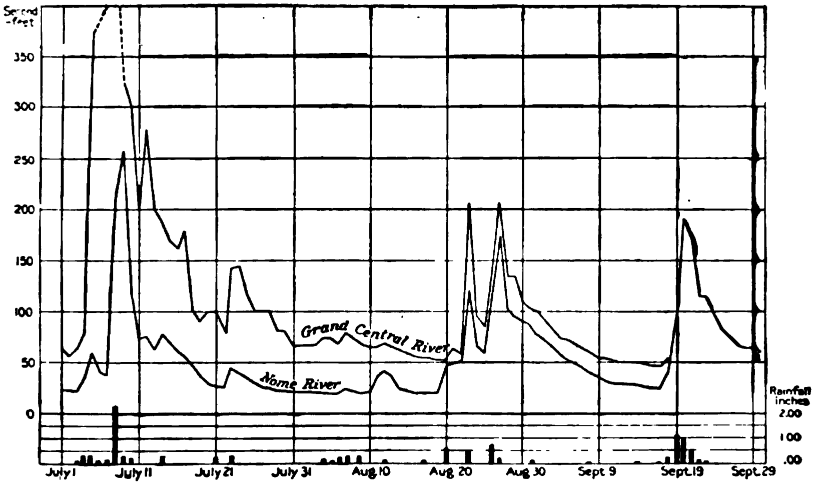


FIG. 1.—Diagram showing flow of Nome River above Miocene intake and of Grand Central River below the forks in 1906.

A notable feature of many drainage basins is the occurrence of limestone springs. These tend to produce a very uniform flow, and when the entire flow is from this source, as in the case of Hobson Creek, the variation in discharge is small. Other streams deriving much of their discharge from springs are Morning Call Creek and Grand Central River in the Nome region, North Fork and Budd Creek in the Kougarok region, and many creeks in the Solomon and Casadepaga regions.

GAGING STATIONS.

The following list gives the points in the Nome region at whi gages were established or discharge measurements made in 1906 an 1907. The numbers refer to Pl. IV.

Gaging stations in Nome region.

1. Nome River above Miocene intake.
2. Buffalo Creek.
3. Dorothy Creek.
4. Miocene ditch at Black Point.
5. Miocene ditch at flume.
6. Hobson Creek at Miocene ditch crossing.
7. David Creek ditch intake.
8. Seward ditch intake.
9. North Fork of Grand Central River at elevation 750 feet.
10. North Fork of Grand Central River at elevation 1,030 feet.
11. West Fork of Grand Central River at elevation 860 feet.
12. West Fork of Grand Central River at elevation 1,010 feet.
13. Crater Lake outlet.
14. Grand Central River below forks.
15. Grand Central River below Nugget Creek.
16. Gold Run.
17. Thompson Creek.
18. Nugget Creek.
19. Copper Creek.
20. Jett Creek.
21. Morning Call Creek.
22. Kruzgamepa River at outlet of Salmon Lake.
23. Crater Creek.
24. Iron Creek below mouth of Canyon Creek.

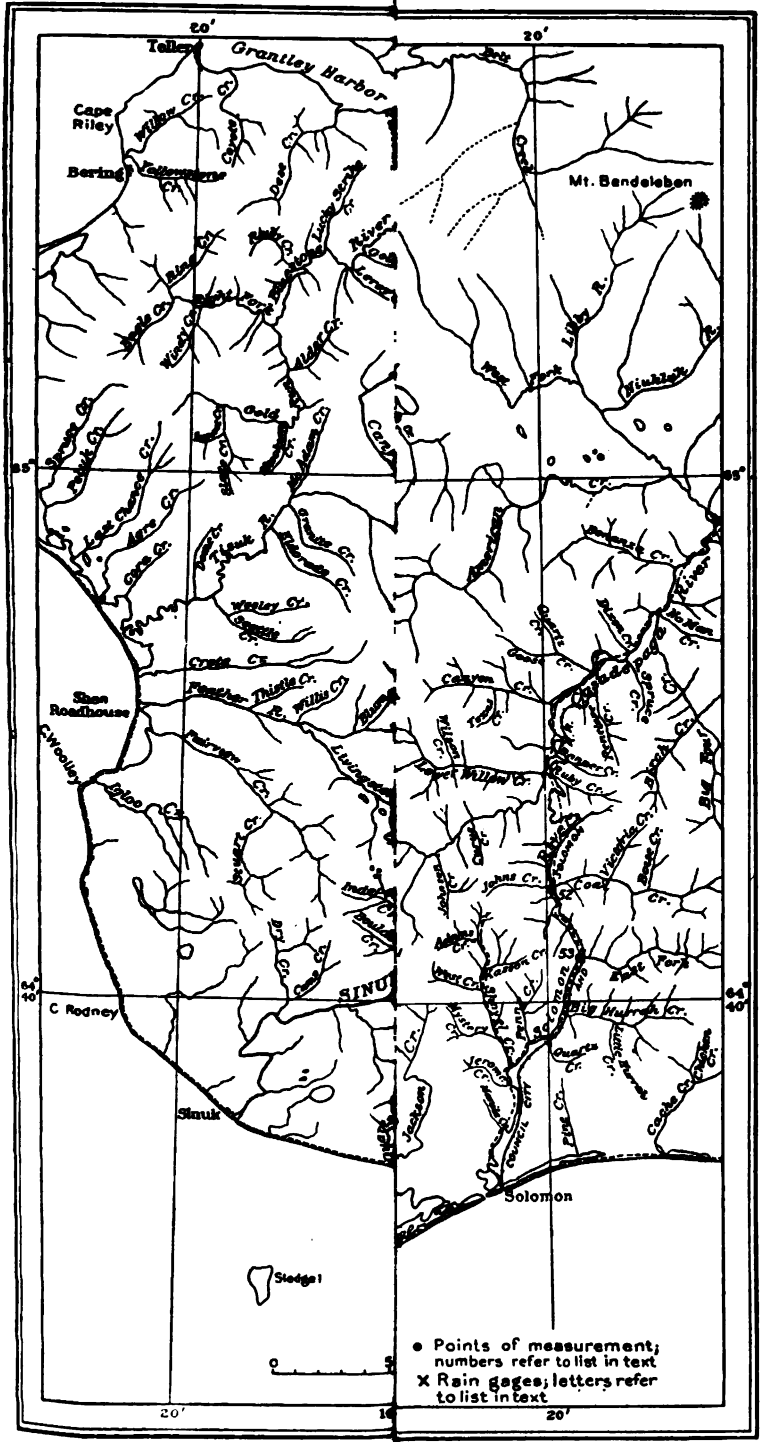
25 Iron (Dome) Creek.

26. Eldorado Creek.
27. Discovery Creek.
28. Canyon Creek.
29. Sinuk River.
30. Windy Creek.
31. North Star Creek.
32. Stewart River.
33. Slate Creek.
34. Josie Creek.
35. Irene Creek.
36. Jessie Creek.
37. Upper Oregon Creek.
38. Slate Creek.
39. Aurora Creek.
40. Penny River at elevation 420 feet.
41. Penny River at elevation 120 feet.
42. Eldorado River.
43. Fall Creek.
44. Glacier Creek.
45. Snow Gulch.
46. Nome River at Pioneer intake and Pioneer ditch.
47. Miocene ditch at Clara Creek.
48. Rock Creek.
49. Slate Creek.
50. Cedric ditch above penstock.
51. Snake River above Glacier Creek.
52. Solomon River below Johns Creek.
53. Solomon River below East Fork.

NOME RIVER DRAINAGE BASIN.

GENERAL DESCRIPTION.

Nome River is formed by the junction of Buffalo and Deep Canyon creeks, which have their sources in the Kigluaik Range. It has a drainage area of 150 square miles and flows in a general southerly direction through a valley having a length of about 40 miles and a width ranging from 4 to 6 miles. The elevation at the headwaters is between 3,000 and 4,000 feet, and the altitude of the ridges that bound the valley on the east and west averages 1,000 feet. The principal tributaries are David, Sulphur, Darling, Buster, and Osborn


20'
20'
Teller
Grantley Harbor
Cape Riley
Willow Cr.
Coyote
Bering
Yellowstone Cr.
Dese Cr.
Lucky Strike Cr.
Ruby Cr.
River
Blue Cr.
Eagle Cr.
Windy Cr.
Right Fork
Alder Cr.
Gold
Mt. Bendeleben
Lilly R.
West Fork
Niukluk R.
Spruce Cr.
Last Chance Cr.
Agra Cr.
Cora Cr.
Tisuk R.
Granite Cr.
Eldorado Cr.
Wesley Cr.
Crete Cr.
Feather Thistle Cr.
R. Willis Cr.
Shea Roadhouse
C. Woolley
Igloo Cr.
Fairview Cr.
Stewart Cr.
Livingston
Bourbon
American
Goose Cr.
Quartz Cr.
Canyon Cr.
Ophir Cr.
Casadepaga
River
Melsing Cr.
Lower Willow Cr.
Ruby Cr.
Bangor Cr.
Johns Cr.
Johnson Cr.
Adams Cr.
Coal
Victoria Cr.
Big Four
Butte Cr.
East Fork
Big Hurrah Cr.
Little Hurrah
Kasson Cr.
Penn Cr.
Solomon
Quartz Cr.
Jerome Cr.
Council City
Pine Cr.
Cache Cr.
Jackson
Independence Cr.
Boulder Cr.
Dry Cr.
Cone Cr.
SINUK
C Rodney
Sinuk
Solomon
Sledge I
65°
64° 40'
0 5 10
20'
20'
● Points of measurement; numbers refer to list in text
X Rain gages; letters refer to list in text

creeks from the east and Divide, Dorothy, Clara, and Hobson creeks from the west.

Nome River is the most important source of water for use in hydraulicking the rich placer deposits on the old beach lines back of Nome. Four ditches have been built to divert water for mining purposes. These systems, with the elevations of their intakes, are the Campion, 610 feet; Miocene, 572 feet; Seward, 407 feet; and Pioneer, 330 feet.

Any additional water supply that may be obtained in other high-level streams can best be brought to the mines by way of the valley of Nome River. During the seasons of 1906 and 1907 the waters of Nugget, Copper, and Jett creeks were diverted over the Nugget divide by branches of the Miocene system.

Discharge measurements made in this drainage area are given in the following pages.

NOME RIVER ABOVE MIOCENE INTAKE.

This station, elevation about 575 feet, is located between the junction of Buffalo and Deep Canyon creeks and the intake of the Miocene ditch. At low water the river at this point has a width of about 30 feet, a depth of 1½ feet, and a mean velocity of 1 foot per second. The gage was read twice daily by employees of the Miocene Ditch Company.

The flow at this station is affected by four ditches—the Campion ditch, which diverts water above the station, and the Jett Creek, David Creek, and Grand Central ditches, which bring in water above the station from areas outside the Nome River basin. In order to obtain the natural flow of the river, the mean flow of the Campion ditch has been added to the flow at the gaging station and the flow of the other three ditches subtracted.

Discharge measurements of Nome River above Miocene intake in 1906-7.

[Elevation, 575 feet.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-ft.*	1907.	*Feet.*	*Sec.-ft.*
June 17 [a]		39	June 22	1.25	141
June 28	0.15	28	June 30	1.09	95
July 3	.00	21	July 10	.95	120
July 5	.45	54.7	July 12	.78	74
July 14	.40	50.5	July 17	.60	43
Do	.82	117	August 4	.44	37
August 3	—.01	21.4	Do	.36	37
August 23	.87	121	August 7	.25	25
Do	.70	87	August 17	.75	82
			Do	.68	72
1907.			September 4	.53	48
June 21	1.25	135	September 9	.96	124

[a] One-half mile above Dorothy Creek

Daily gage height and discharge of Nome River at Miocene intake, 1906-7.

[Drainage area, 15 square miles.]

Day.	1906.						1907.							
	July.		August.		September.		June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Ft.	*S.ft.*	*Ft.*	*S.ft.*	*Ft.*	*S.ft.*	*Ft.*	*S.ft.*	*Ft.*	*S.ft.*	*Ft.*	*S.ft.*	*Ft.*	*S.ft.*
1	.....	23	0.02	22	0.61	78	.....	.....	1.19	122	0.51	38	0.57	54
2	.....	23	.00	21	.57	72	.....	.....	1.06	88	.49	36	.50	[illegible]
3	0.00	21	−.01	21	.52	65	.....	.....	1.03	80	.48	35	.50	47
4	.25	35	−.02	20	.46	57	.....	.....	.94	117	.45	33	.53	[illegible]
5	.48	59	−.04	20	.42	52	.....	.....	.94	117	.33	32	.45	[illegible]
6	.31	40	−.04	20	.40	49	.....	.....	1.08	168	.33	32	.46	[illegible]
7	.28	37	+ 09	25	.36	45	.....	.....	1.04	152	.27	27	.41	[illegible]
8	1.31	214	+.04	23	.36	39	.....	.....	.90	103	28	28	.44	[illegible]
9	1.50	260	−.02	20	.27	37	.....	.....	.84	87	27	27	.92	113
10	.85	119	.00	21	.21	32	.....	.....	.88	97	.22	24	1.62	[illegible]
11	.58	73	+.26	36	.18	30	.....	.....	.92	110	.22	24	1.29	204
12	.60	76	.34	43	.18	30	.....	.....	.78	74	.22	24	.90	[illegible]
13	.50	62	.28	37	.18	30	.....	.....	.80	78	.20	23	.79	[illegible]
14	.61	78	.10	25	.15	28	.....	.....	.75	68	.24	25	.77	[illegible]
15	.56	70	.04	23	.12	26	2.14	384	.65	53	.20	23	.78	[illegible]
16	.49	61	.03	22	.10	25	1.44	192	.65	53	.51	48	.66	66
17	.45	56	.02	22	.10	25	1.29	149	.64	52	.74	79	.60	58
18	.38	47	.00	21	.32	41	2.12	378	.64	52	.70	72	.58	56
19	.26	36	.00	21	.70	92	1.60	237	.72	63	.64	64	.58	56
20	.16	29	+.38	47	1.22	194	1.36	169	.80	78	.60	58	50	47
21	14	27	.41	50	1.12	172	1.26	141	.94	117	.52	49	51	48
22	.13	27	.42	52	.83	115	1.29	149	.70	60	.50	47	32	31
23	.36	45	.87	123	.82	114	1.28	146	.71	62	.46	42	42	39
24	.31	40	.53	66	.74	99	1.66	253	.69	59	.46	42	.43	39
25	.26	36	.48	59	.65	84	1.56	225	.66	54	.42	39	.38	35
26	.18	30	.80	110	.60	76	1.55	222	.64	52	.62	61	.35	33
27	.12	26	1.14	176	.54	68	1.38	174	.56	43	.67	68	32	31
28	.09	25	.78	106	.52	65	1.26	141	.50	37	.60	58	31	30
29	.06	23	.72	96	.52	65	1.31	155	.48	35	62	61	.32	31
30	.04	23	.70	92	.50	62	1.20	124	.52	39	.78	86	.36	34
31	.02	22	.62	79	.....	.....	.....	.....	.56	43	.62	61	.....	.....
Mean at gaging station	.....	56.2	.....	49.0	.....	65.6	.....	202	.....	77.8	.....	44.1	.....	66.7
Mean of Campion ditch	.....	5.2	.....	14.4	.....	15.8	.....	0	.....	7.3	.....	12.9	.....	12.5
Total	.....	61.4	.....	63.4	.....	81.4	.....	202	.....	85 1	.....	57.0		79.2
David Creek ditch	.....	[a]6	.....	6	.....	[a]7	.....	.....	.....	5.5	.....	11.8	.....	9.0
Jett Creek ditch	.....	[a]1	.....	[a]3	.....	[a]5	.....	.....	.....	3 1	.....	6.1	.....	2 8
Grand Central ditch	.....	[a]3	.....	[a]4	.....	[a]5	.....	.....	.....	4.3	.....	6.2	.....	9.0
Total	.....	10	.....	13	.....	17	.....	.....	.....	12.9	.....	24.1	.....	20.8
Natural flow of Nome River	.....	51.4	.....	50.4	.....	64.4	.....	202	.....	72.2	.....	32.9	.....	58.4
Run-off per square mile	.....	3 43	.....	3.36	.....	4.29	.....	13.5	.....	4.81	.....	2.19	.....	3.89
Run-off, depth in inches	.....	3.95	.....	3.87	.....	4.79	.....	8.03	.....	5 54	.....	2.52	.....	4.34

[a] Approximate.

NOTE.—Discharges for 1907 were computed from three rating curves, covering June 15 to July 3, July 4 to August 4, and August 5 to September 30. The channel below the gage was scraped out with horses on July 1 to 7 and August 4.

Natural daily discharge, in second-feet, of Nome River at Miocene intake, 1907.

Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.
1	....	122	26	43	18	378	46	57	41
2	....	88	26	38	19	237	53	45	43
3	....	80	25	36	20	169	66	37	40
4	....	117	24	40	21	141	100	29	35
5	....	117	23	35	22	149	49	30	22
6	....	168	23	34	23	146	48	29	18
7	....	159	19	29	24	253	44	28	31
8	....	108	22	29	25	225	39	25	30
9	....	88	22	101	26	222	37	50	30
10	....	101	19	307	27	174	29	56	28
11	....	112	19	200	28	141	26	44	27
12	....	70	19	112	29	155	23	46	26
13	....	76	18	79	30	124	30	75	18
14	....	63	20	74	31	....	33	49	....
15	384	51	16	85					
16	192	52	34	63	Mean	202	72.2	32.9	58.4
17	149	43	63	57					

NOME RIVER AT PIONEER INTAKE AND PIONEER DITCH.

These stations were established to obtain the total discharge of Nome River available for the three ditches. Both were located about one-fourth mile below the diversion dam of the Pioneer ditch.

Gage heights were obtained for only a short period in August, when readings were made by employees of the Pioneer Mining Company.

To obtain the natural flow of the river, the discharge of the Seward ditch at intake and of the Miocene ditch at Clara Creek has been added, and that of the two ditches discharging over Nugget divide subtracted. The run-off per square mile thus obtained is slightly greater than that of the river at the Miocene intake for the same period. The discharge at this station can, therefore, be conservatively estimated at the same rate per square mile as that at the upper station.

Discharge measurements of Nome River at Pioneer intake and Pioneer ditch, 1907.

[Elevation, 330 feet.]

NOME RIVER.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec. ft.*		*Feet.*	*Sec. ft.*
July 9	1.89	132	August 20	1.39	25
July 18	1.58	58	August 29	1.49	46
August 9	1.13	3			

PIONEER DITCH.

July 18	1.22	18.7	August 20	1.41	24.3
July 24	1.35	22.2	August 29	1.44	25.6
August 9	1.19	16.8			

Daily gage-height and discharge of Nome River and diversions at Pioneer intake, August, 1907.

[Drainage area, 38 square miles.]

Day.	Nome River.		Pioneer ditch.		Seward ditch.	Miocene ditch.	Total.	Diverted over Nugget divide.	Net total.	Nome River at Miocene intake.
	Gage height.	Discharge.	Gage height.	Discharge.						
	Feet.	*Sec. ft.*	*Feet.*	*Sec. ft.*	*Sec. ft.*	*Sec. ft.*	*Sec. ft.*	*Sec. ft.*	*Sec. ft.*	*Sec. ft.*
21	1.40	29	1.43	25.0	29.0	34.0	117	17.5	100	[illegible]
22	1.30	16	1.40	24.0	26.9	34.0	101	15.5	86	[illegible]
23	1.30	16	1.42	24.7	27.9	34.0	103	14.2	89	[illegible]
24	1.25	12	1.42	24.7	27.9	33.0	98	16.2	82	[illegible]
25	1.25	12	1.48	26.8	29.0	34.6	103	14.9	88	[illegible]
26	1.55	52	1.48	26.8	29.0	35.2	143	14.2	129	[illegible]
27	1.60	62	1.40	24.0	27.2	35.2	148	14.9	133	[illegible]
28	1.57	55	1.38	23.4	27.2	35.2	140	15.6	124	44
29	1.52	47	1.30	20.8	27.9	35.2	131	16.9	114	[illegible]
30	1.75	95	1.39	23.7	28.6	35.2	183	14.9	168	[illegible]
31	1.55	52	1.36	22.7	28.6	35.2	139	14.9	124	[illegible]
Mean		40.7		24.2	28.1	34.6	128	15.4	112	41.9
Run-off per square mile									2.95	2.90

BUFFALO CREEK.

Buffalo Creek rises in a high U-shaped valley on the south side of the Kigluaik Mountains, and after a steep descent joins Deep Canyon Creek, forming Nome River. Measurements were made as follows:

Discharge measurements on Buffalo Creek in 1906.

[Elevation, 800 feet; drainage area, 4.4 square miles.]

	Second-feet.
June 28	18.1
July 6	23.3
August 3	9.1

DAVID CREEK.

David Creek is the first large tributary of Nome River below the junction of Buffalo and Deep Canyon creeks. Its valley has a northwestward exposure, and holds a considerable amount of snow well into the summer.

The discharge of the David Creek lateral of the Miocene ditch (see p. 33) is equal to that of the creek at the point of diversion at times of low water. This has been compared with the natural flow of Nome River for five such periods, as follows:

Comparison of flow of David Creek and Nome River at Miocene intake, 1907.

Date.	Nome River.	David Creek.	David Creek in per cent of Nome River.
	Sec. ft.	*Sec. ft.*	
July 25–31	31	14.3	46
August 1–16	22	10.4	47
August 19–25	32	13.8	43
September 3–8	34	11.9	35
September 19–30	32	11.2	35

The above table shows that the discharge of David Creek was from 47 to 35 per cent of that of Nome River. The discharge for other periods than those given has therefore been taken as 45 per cent of that of Nome River for July, 40 per cent for August, and 35 per cent for September.

Monthly discharge of David Creek at Miocene intake, 1907.

[Drainage area, 4.3 square miles.

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
July	76	10.9	32.2	7.49	8.64
August	30	8.9	14.2	3.30	3.80
September	107	8.3	20.7	4.81	5.37
92 days	107	8.3	22.4	5.20	17.81

DOROTHY CREEK.

Dorothy Creek, which enters Nome River from the southwest, is a short, precipitous stream. It receives water from the Campion ditch, as noted on page 35. The following discharge measurements were made above the outlet of the ditch:

Discharge measurements on Dorothy Creek in 1906.

[Elevation, 500 feet; drainage area, 2.7 square miles.]

	Second-feet.
June 16	5.1
July 29	3.0
August 18	2.9

HOBSON CREEK.

Hobson Creek is one of the most interesting and valuable streams in the Nome region. It rises south of Dorothy Creek, flows southward and discharges into Nome River about 18 miles from the seacoast. It is about 4 miles long and very steep. Its only important tributary is Manila Creek, which becomes dry at low water. Hobson Creek is notable for the large limestone springs from which it receives its water. The highest of these springs emerges just above the dam at the Miocene ditch crossing. Above them a trench has been dug across the stream to solid rock, and no flow was intercepted. Between the dam and the mouth of Manila Creek there are many springs, none of them very large, but giving an aggregate discharge nearly equal to that above the Miocene intake.

At low water the Miocene ditch obtains nearly half its water supply from Hobson Creek. Laterals have also been built to the other ditches, that to the Seward lying on the east bank and the Pioneer branch on the west bank.

The water from Hobson Creek is valuable not only on account of its remarkably uniform flow but also on account of its high temperature, which prevents the formation of slush ice during cold nights and makes it possible to run the ditches somewhat longer than they could be with Nome River water alone.

In the opinion of employees of the Miocene Ditch Company the extreme range of the discharge of the upper springs is from 8 to 32 second-feet during the summer season. During the winter they probably run somewhat lower, but always remain open.

Daily discharge, in second-feet, of Hobson Creek at Miocene intake, 1907.

[Elevation, 500 feet; drainage area, 2.6 square miles.]

Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.
1		25.5	20.4	17.7	20		22.6	14.3	19.5
2		24.9	18.7	17.3	21		23.0	15.4	19.7
3		23.8	19.1	17.3	22		21.1	14.7	18.3
4		22.7	19.3	17.7	23		22.3	14.3	22.3
5		22.7	19.2	17.3	24		23.5	16.8	20.6
6		21.1	18.9	16.9	25		22.7	18.3	19.7
7		19.6	19.4	16.5	26		24.2	17.3	19.3
8		25.8	17.3	17.9	27		21.8	17.3	17.7
9		24.5	18.1	16.6	28	26.7	21.4	17.3	19.1
10		22.7	18.2	18.2	29	25.8	20.2	17.7	19.3
11		23.0	16.2	20.0	30	25.0	20.9	17.7	19.7
12		24.0	16.7	20.5	31		21.2	17.7	
13		23.0	16.4	21.0					
14		23.0	16.4	21.9	Mean	25.8	22.6	17.1	19.1
15		19.7	16.3	20.3	Run-off per square mile	9.92	8.69	6.58	7.35
16		23.1	16.9	20.6					
17		21.4	14.7	20.6	Run-off, depth in inches	1.11	10.02	7.59	8.20
18		23.2	14.7	20.7					
19		22.3	14.3	20.3					

NOTE.—These discharges were obtained by subtracting those of the Miocene ditch above the dam from the flow of the ditch below the dam, and adding the amount spilled from the waste way, as estimated by C. A. McDermith. Some water was being spilled from July 16 to 26 and September 12 to 30.

Discharge measurements of Hobson Creek below Manila Creek and diversions, 1907.

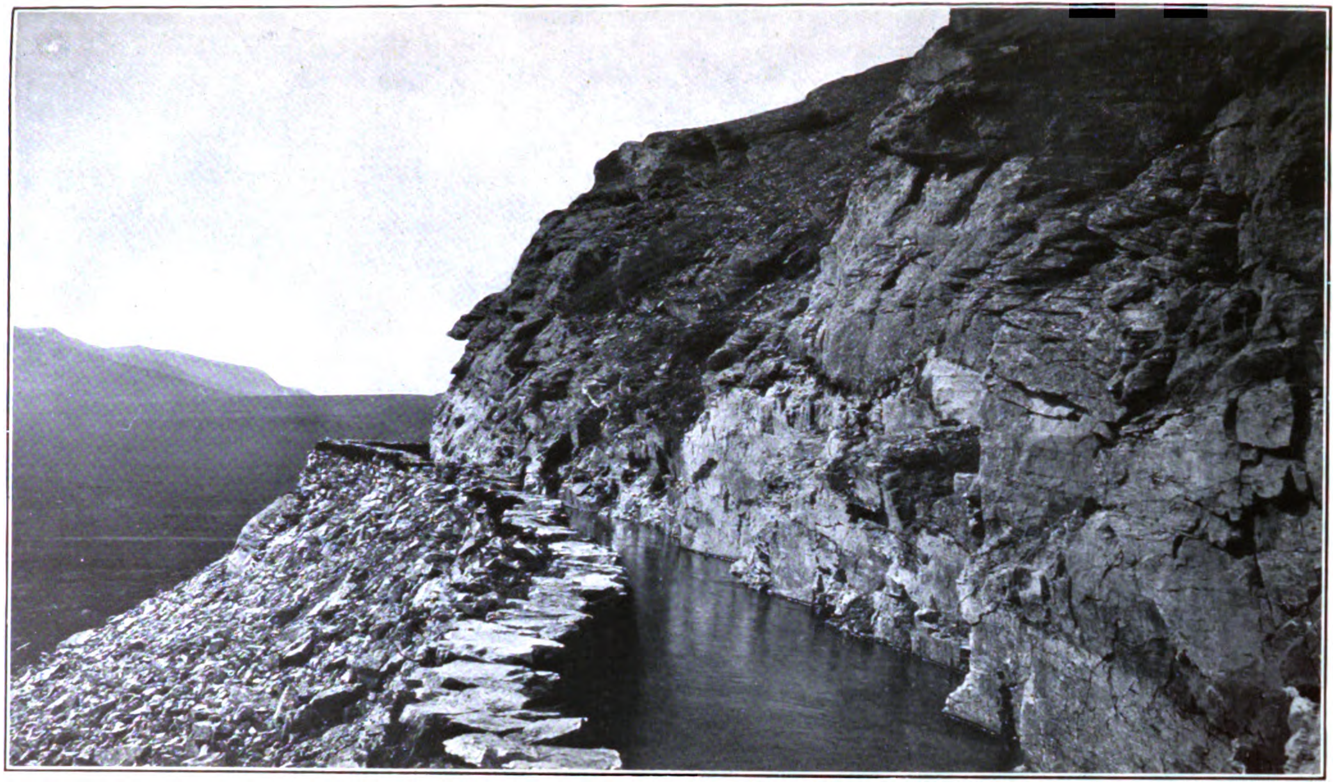
[Drainage area, 5.1 square miles.

Point of measurement.	July 2.	July 9.	July 19.	Aug. 9.	Sept. 28
	Sec. ft.	*Sec. ft.*	*Sec. ft.*	*Sec. ft.*	*Sec. ft.*
Miocene intake	24.9	24.5	22.3	18.1	19.3
Seward lateral	0.0	5.2	5.2	4.3	4.5
Pioneer lateral	0.0	0.0	0.0	0.0	5.5
Hobson Creek below Manila Creek	25.0	21.0	17.7	10.7	5.0
	49.9	50.7	45.2	33.1	34.3

THE MIOCENE DITCH SYSTEM.

GENERAL DESCRIPTION.

The Miocene ditch system includes 31 miles of main ditch and 31 miles of lateral feeders and distributing ditches, 8 miles of which are under construction. (See Pl. III, *B*, and Pl. V.) This ditch diverts water from upper Glacier Creek, upper Snake River, Nome River and



ROCK CUT AROUND CAPE HORN ON MIOCENE DITCH.

its tributaries, and from the Grand Central River drainage for use on claims along lower Glacier, Dexter, and Anvil creeks.

The first section of this system was built in 1901, from upper Glacier Creek to Snow Gulch, this being the first ditch in Seward Peninsula. In 1902 an extension was made from Ex to Hobson Creek, and in 1903 the ditch was extended to the head of Nome River, these three sections constituting the main line of the system, with a length of 31 miles. The elevation of the intake is 572 feet and that of the lower end 420 feet, giving a fall of 152 feet. This fall varies at different points along the ditch, ranging from 3.17 to 7 feet per mile. There are two siphons, one at Dorothy Creek, 24 inches by 300 feet, which carries about 40 second-feet, and one at Manila Creek, 40 inches by 1,000 feet. Below Willow Creek there is a 1,100-foot flume. The main ditch has an average width of 8 feet above and 10 feet below Hobson Creek, and a capacity of 60 second-feet. The mean flow is about 40 second-feet.

The water is delivered from the end of the ditch on claims along Glacier Creek; on Anvil Creek by a tunnel 1,800 feet long and 4 by 6 feet in cross section, built in 1903 and 1904; and on Dexter Creek by a ditch from Ex around the south side of King Mountain.

The lateral feeders, in order up the ditch, are: (1) From upper Glacier Creek to Ex (this was the upper portion of the first section of the main ditch); (2) from Grouse and Cold creeks to flume; (3) from upper New Eldorado Creek to Buster Creek (it was originally intended to connect this feeder with the main ditch by a siphon across Nome River, but in 1907 it was extended to producing ground on Buster Creek); (4) the David Creek ditch, which empties into Nome River above the intake; (5) the Jett Creek ditch, which takes water from Jett and Copper creeks and carries it over the Nugget divide; (6) the Grand Central ditch, which is under construction (this ditch diverts water from Nugget Creek and will tap the headwaters of Grand Central River).

As a rule water can not be turned into ditches in this region before July 1, as there is too much frost in the ground. In 1906 the water of Hobson Creek was turned into the ditch about June 20 and that of Nome River about June 26, but before July 1 it was turned out frequently to permit repairs. The ditch was also out of use on account of a break from July 8 to 11, inclusive, after which the water ran almost continually. The Nome River water was turned out October 12, and the Hobson Creek water on the morning of the 13th. This season was somewhat longer than usual. In 1907 the Hobson Creek water was turned in on June 27 and that from Nome River on July 3, but the ditch was not run to its full capacity until July 27. All water was turned out on October 3. A break occurred just below Hobson

Creek on September 10 and all water turned out for thirty-three hours; this was practically the only interruption in the flow.

During 1906 two gaging stations were maintained on the ditch—one at Black Point, about 1 mile below the intake, to determine the amount of water diverted from Nome River, and one at the flume, which gives practically the total amount delivered at the mines.

In 1907 three additional stations were established—at Clara Creek, above Hobson Creek, and below Hobson Creek. The difference in discharge at the last two gives the flow of the creek (p. 24). The difference between the flow at any of the other stations and that at the one below it gives the loss by seepage in that portion of the ditch. The Grouse Creek lateral joins the main ditch between Hobson Creek and the flume and sometimes causes an increased discharge at the flume as compared with that at the creek station. Measurements of this lateral are given on page 35. The distances by ditch between stations are as follows: Black Point to Clara Creek, 7.1 miles; Clara Creek to Hobson Creek, 4.9 miles; Hobson Creek to the flume, 4.2 miles; the flume to the Ex, 9.5 miles. Measurements at the Ex are given on page 30. The flow of the Glacier Creek lateral about equals the seepage below the flume.

The results of measurements at the above-named stations are given in the following pages. All the gages were read by employees of the Miocene Ditch Company from two to four times a day. Gage readings taken after September 30 were unreliable, on account of the slush ice that was running, and the discharge for the last few days in September may be slightly too large, for the same reason.

Discharge measurements of Miocene ditch at Black Point, 1906-7.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec. ft.*	1907.	*Feet.*	*Sec. ft.*
July 7	0.80	31.8	July 4	0.51	21
July 13	.89	34.1	July 10	.57	24
July 21	.71	27.5	July 17	.79	[illegible]
July 27	.68	25.7	August 2	.96	[illegible]
July 29	.46	20.6	August 6	.62	25.1
August 2	.39	18.1	August 16	91	33.5
August 11	1.20	44.7	Do	1.13	42.5
August 23	1.30	48.3			
September 11	.85	30.7			
September 25	1.10	38.2			

Daily gage height and discharge of Miocene ditch at Black Point, 1906–7.

Day.	1906.						1907.					
	July.		August.		September.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	0.70	27	0.40	18.8	1.20	43.5	......	....	1.05	38.8	1.15	42.2
2	.70	27	.38	18.5	1.20	43.5	......	....	.98	36.5	1.15	42.2
3	.60	24	.35	18	1.20	43.5	0.52	22.3	.91	34.2	1.15	42.2
4	.85	31.5	.34	17.8	1.20	43.5	.50	21.7	.85	32.2	1.15	42.2
5	.95	34.8	.33	17.7	1.20	43.5	.50	21.7	.80	30.7	1.15	42.2
6	.88	32.4	.34	17.8	1.20	43.5	.45	20.4	.68	27.0	1.15	42.2
7	.85	31.5	.52	21.6	1.17	42.4	.40	19.2	.61	24.9	1.04	38.4
8	......	0	.48	20.6	1.04	37.9	.48	21.1	.64	25.8	1.08	39.8
9	......	0	.37	18.3	1.00	36.5	.48	21.1	.61	24.9	1.10	40.5
10	......	0	.40	18.8	.98	35.8	.50	21.7	.52	22.3	.80	30.7
11	.50	21	.81	30.3	.82	30.6	.50	21.7	.52	22.3	.48	21.1
12	1.00	36.5	.82	30.6	.80	30	.50	21.7	.52	22.3	.98	36.5
13	1.00	36.5	.96	35.1	.80	30	.50	21.7	.50	21.7	1.15	42.2
14	1.00	36.5	.60	24	.76	28.8	.50	21.7	.55	23.1	1.08	39.8
15	1.20	43.5	.50	21	.72	27.6	.80	30.7	.45	20.4	1.00	37.1
16	1.10	40	.50	21	.66	25.8	.80	30.7	.90	33.8	1.00	37.1
17	1.10	40	.45	19.9	.64	25.2	.80	30.7	1.15	42.2	1.00	37.1
18	1.10	40	.39	18.6	.78	29.4	.80	30.7	1.15	42.2	1.00	37.1
19	.92	33.7	.46	20.1	.80	30	.80	30.7	1.15	42.2	1.08	39.8
20	.70	27	.86	31.8	.58	23.4	.80	30.7	1.16	42.6	1.15	42.2
21	.70	27	1.12	40.7	.69	26.7	.80	30.7	1.16	42.6	1.08	39.8
22	.62	24.6	1.03	37.0	.92	33.7	.80	30.7	1.16	42.6	1.15	42.2
23	.85	31.5	1.17	42.4	1.00	36.5	.80	30.7	1.10	40.5	1.15	42.2
24	.95	34.8	1.19	43.2	.96	35.1	.80	30.7	1.08	39.8	1.06	39.1
25	.92	33.7	1.20	43.5	1.05	38.2	.85	32.2	1.02	37.7	1.00	37.1
26	.75	28.5	1.17	42.4	1.06	38.6	.86	32.6	1.15	42.2	1.04	38.4
27	.62	24.6	1.16	42.1	1.22	44.2	1.00	37.1	1.16	42.6	.98	36.5
28	.54	22.2	1.20	43.5	1.20	43.5	.94	35.1	1.16	42.6	.94	35.1
29	.50	21	1.20	43.5	1.20	43.5	.94	35.1	1.16	42.6	1.02	37.7
30	.45	19.9	1.20	43.5	1.20	43.5	.96	35.8	1.15	42.2	1.12	41.2
31	.42	19.2	1.20	43.5	......	....	1.10	40.5	1.15	42.2	......	....
Mean	......	27.4	......	29.2	......	35.9	......	28.0	......	34.4	......	38.7

Discharge measurements of Miocene ditch at Clara Creek, 1907.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 9	0.50	18.2	August 20	0.91	35.2
July 18	.79	27.7	August 29	.92	34.7
August 9	.60	21.1	September 27	.88	34.0

Daily gage height and discharge of Miocene ditch at Clara Creek. 1907.

Day.	July.		August.		Septem	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.89	33.5	0.92	35.2
2			.85	31.5	.92	35.2
3		[a] 18.0	.84	31.0	.92	35.2
4		[a] 19.0	.80	29.0	.92	35.2
5		[a] 19.0	.78	28.1	.92	35.2
6		[a] 19.0	.66	23.1	.91	34.6
7	0.52	18.8	.60	21.0	.89	33.5
8	.55	19.6	.58	20.4	.88	33.0
9	.50	18.2	.55	19.6	.92	35.2
10	.54	19.3	.52	18.8	.69	24.2
11	.56	19.9	.50	18.2	.70	24.5
12	.46	17.2	.50	18.2	.88	33.0
13	.50	18.2	.48	17.7	.95	37.0
14	.51	18.5	.52	18.8	.95	37.0
15	.71	25.0	.48	17.7	.94	36.4
16	.82	30.0	.72	25.4	.91	34.6
17	.75	26.8	.92	35.2	.91	34.6
18	0.82	30.0	0.91	34.6	0.91	[illegible]
19	.79	28.6	.90	34.0	.92	[illegible]
20	.79	28.6	.91	34.6	.85	[illegible]
21	.81	29.5	.90	34.0	.95	[illegible]
22	.82	30.0	.90	34.0	.88	[illegible]
23	.80	29.0	.90	34.0	.88	[illegible]
24	.80	29.0	.88	33.0	.92	[illegible]
25	.80	29.0	.91	34.6	.90	[illegible]
26	.82	30.0	.92	35.2	.92	[illegible]
27	.88	33.0	.92	35.2	.88	[illegible]
28	.88	33.0	.92	35.2	.84	[illegible]
29	.83	30.5	.92	35.2	.88	[illegible]
30	.89	33.5	.92	35.2	.88	[illegible]
31	.92	35.2	.92	35.2		
Mean		25.4		28.7		[illegible]

[a] Estimated from Black Point records.

Discharge measurements of Miocene ditch above Hobson Creek, 1907.

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
July 9	0.88	17.6
July 19	1.25	25.7
August 9	.98	18.8
August 29	1.38	[illegible]
September 27	1.36	[illegible]
September 28	1.30	[illegible]

Daily gage height and discharge of Miocene ditch above Hobson Creek. 1907.

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.37	33.1	1.38	33.5
2			1.31	31.0	1.38	33.5
3	0.80	14.7	1.30	30,6	1.38	33.5
4	.90	17.3	1.20	27.0	1.38	33.5
5	.90	17.3	1.18	26.3	1.38	33.5
6	.90	17.3	1.04	21.5	1.38	33.5
7	.93	18.1	.97	19.3	1.35	32.4
8	.77	13.9	.95	18.7	1.31	31.0
9	.89	17.0	.99	19.9	1.39	33.8
10	.90	17.3	.90	17.3	1.42	34.9
11	.89	17.0	.88	16.8		0
12	.85	16.0	.86	16.3	1.34	32.0
13	.89	17.0	.84	15.7	1.40	34.2
14	.89	17.0	.92	17.9	1.40	34.2
15	1.22	27.7	.80	14.7	1.37	33.1
16	1.17	25.9	1.02	20.8	1.36	32.8
17	1.21	27.4	1.39	33.8	1.36	32.8
18	1.20	27.0	1.38	33.5	1.37	33.1
19	1.20	27.0	1.38	33.5	1.38	33.5
20	1.16	25.6	1.38	33.5	1.35	32.4
21	1.21	27.4	1.38	33.5	1.39	[illegible]
22	1.21	27.4	1.38	33.5	1.39	33.8
23	1.23	28.1	1.37	33.1	1.29	30.2
24	1.24	28.4	1.29	30.2	1.39	[illegible]
25	1.22	27.7	1.30	30.6	1.39	[illegible]
26	1.22	27.7	1.38	33.5	1.39	[illegible]
27	1.33	31.7	1.38	33.5	1.35	32.4
28	1.33	31.7	1.38	33.5	1.27	29.5
29	1.28	29.9	1.38	33.5	1.30	30.0
30	1.27	29.5	1.38	33.5	1.35	32.4
31	1.38	33.5	1.38	33.5		
Mean		23.6		27.4		31.8

Discharge measurements of Miocene ditch below Hobson Creek, 1907.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 2	1.60	24.8	July 24	2.38	49.4
July 9	2.08	39.1	September 27	2.38	52.0
July 19	2.30	46.8			

Daily gage height and discharge of Miocene ditch below Hobson Creek, 1907.

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.63	25.5	2.46	53.5	2.40	51.2
2			1.60	24.9	2.36	49.7	2.39	50.8
3			1.74	28.3	2.36	49.7	2.39	50.8
4			2.10	40.0	2.27	46.3	2.40	51.2
5			2.10	40.0	2.25	45.5	2.39	50.8
6			2.05	38.4	2.11	40.4	2.38	50.4
7			2.03	37.7	2.06	38.7	2.34	48.9
8			2.09	39.7	1.98	36.0	2.34	48.9
9			2.14	41.5	2.04	38.0	2.38	50.4
10			2.10	40.0	1.95	35.5	2.45	53.1
11			2.10	40.0	1.89	33.0		0
12			2.10	40.0	1.89	33.0	2.33	48.5
13			2.10	40.0	1.86	32.1	2.40	51.2
14			2.10	40.0	1.93	34.3	2.37	50.1
15			2.30	47.4	1.83	31.0	2.30	47.4
16			2.29	47.0	2.03	37.7	2.30	47.4
17			2.31	47.8	2.33	48.5	2.30	47.4
18			2.32	48.2	2.32	48.2	2.31	47.8
19			2.31	47.8	2.31	47.8	2.31	47.8
20			2.30	47.4	2.31	47.8	2.34	48.9
21			2.30	47.4	2.34	48.9	2.33	48.5
22			2.33	48.5	2.32	48.2	2.32	48.2
23			2.38	50.4	2.30	47.4	2.33	48.5
24			2.38	50.4	2.29	47.0	2.38	50.4
25			2.34	48.9	2.34	48.9	2.35	49.3
26			2.38	50.4	2.39	50.8	2.37	50.1
27			2.46	53.5	2.39	50.8	2.37	50.1
28	1.68	26.7	2.45	53.1	2.39	50.8	2.33	48.5
29	1.64	25.8	2.37	50.1	2.40	51.2	2.35	49.3
30	1.60	25.0	2.38	50.4	2.40	51.2	2.37	50.1
31			2.49	54.7	2.40	51.2		
Mean		25.8		43.8		45.3		47.9

Discharge measurements of Miocene ditch at flume, 1906–7.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-ft.*	1907.	*Feet.*	*Sec.-ft.*
July 4	0.95	29.8	July 2	1.58	36
July 27	1.08	36.5	July 3	1.51	32
August 2	.81	28.3	July 19	1.99	50
September 11	1.50	43.9	July 23	2.09	55
September 25	1.85	58.2	August 10	1.63	33
September 26	1.65	48.5	August 29	2.05	51
			September 28	2.02	50

Daily gage height and discharge of Miocene ditch at flume, 1906-7.

Day.	1906.						1907.					
	July.		August.		September.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	0.98	31.6	0.82	27.2	1.71	51.5	1.56	33.5	2.05	52.0	2.02	[illegible]
2	.95	30.8	.81	27	1.71	51.5	1.56	33.5	2.00	50.0	2.00	[illegible]
3	.92	29.9	.84	27.8	1.70	51.2	1.56	33.5	1.92	46.8	2.00	[illegible]
4	1.00	32.1	.89	29.1	1.70	51.2	1.74	39.6	1.86	44.4	2.00	[illegible]
5	1.08	34.3	.90	29.4	1.70	51.2	1.75	40.0	1.82	42.8	2.00	[illegible]
6	1.09	34.5	.91	29.7	1.69	50.9	1.75	40.0	1.78	41.2	2.00	[illegible]
7	1.12	35.3	.93	30.2	1.66	50.1	1.70	38.0	1.70	38.0	1.99	[illegible]
8	(a)	0	.98	31.6	1.68	50.6	1.77	40.8	1.68	37.3	1.98	[illegible]
9	(a)	0	.90	29.4	1.63	49.2	1.80	42.0	1.69	37.7	2.04	[illegible]
10	(a)	0	.88	28.9	1.54	46.7	1.86	44.4	1.63	35.6	2.10	[illegible]
11	.79	26.4	1.01	32.4	1.49	45.3	1.77	41.0	1.58	34.0	(a)	
12	1.10	34.8	1.13	35.6	1.46	44.5	1.80	42.0	1.56	33.5	1.98	[illegible]
13	1.26	39.1	1.23	38.3	1.45	44.2	1.85	44.0	1.54	32.9	2.02	[illegible]
14	1.29	39.9	1.02	32.6	1.41	43.2	1.85	44.0	1.58	34.0	2.12	[illegible]
15	1.28	39.7	.94	30.5	1.40	42.9	1.92	46.8	1.50	31.8	2.10	[illegible]
16	1.39	42.6	.92	29.9	1.34	41.3	1.80	42.0	1.71	38.4	2.10	[illegible]
17	1.35	41.6	.91	29.7	1.31	40.5	1.95	48.0	1.96	48.4	2.10	[illegible]
18	1.35	41.6	.87	28.6	1.47	44.8	1.95	48.0	1.95	48.0	2.11	[illegible]
19	1.28	39.7	.86	28.3	1.48	45.1	1.95	48.0	1.92	46.8	2.12	[illegible]
20	1.19	37.2	1.10	34.8	1.52	46.2	1.95	48.0	1.94	47.6	2.10	[illegible]
21	1.16	36.4	1.29	39.9	1.58	47.8	2.00	50.0	1.95	48.0	2.13	[illegible]
22	1.11	35.1	1.28	39.7	1.65	49.8	2.00	50.0	1.93	47.2	2.08	[illegible]
23	1.19	37.2	1.32	40.7	1.61	48.7	2.02	50.8	1.92	46.8	2.04	[illegible]
24	1.09	34.5	1.40	42.9	1.60	48.4	1.99	49.6	1.92	46.8	2.09	[illegible]
25	1.26	39.1	1.44	44	1.71	51.5	2.01	50.4	1.95	48.0	2.09	[illegible]
26	1.17	36.7	1.55	47	1.63	49.2	2.05	52.0	2.00	50.0	2.08	[illegible]
27	1.07	34	1.34	41.3	1.75	52.6	2.08	53.2	2.04	51.6	2.08	[illegible]
28	.98	31.6	1.46	44.5	1.76	52.9	2.06	52.4	2.01	50.4	2.03	[illegible]
29	.95	30.8	1.51	45.9	1.79	53.7	2.04	51.6	2.04	51.6	2.03	[illegible]
30	.91	29.7	1.56	47.3	1.80	54	2.00	50.0	2.06	52.4	2.04	[illegible]
31	.88	28.9	1.50	45.6	......	....	2.03	51.2	2.03	51.2	......	......
Mean	......	b 31.8	......	35.2	......	48.4	......	45.1	......	44.0	......	[illegible]

a Ditch broken by heavy rains.

b For 28 days, 35.2 second-feet.

NOTE.—About 28 second-feet turned in June 28, 1907.

Discharge measurements of Miocene ditch below the Ex, 1907.

Date.	Glacier branch.	Dexter branch.	Total.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*
June 26	8.8	0.	[illegible]
July 6	27.6	16.0	[illegible]
July 19	31.5	14.0	[illegible]
September 4	34.3	13.0	[illegible]

JETT CREEK DITCH.

The Jett Creek ditch was constructed during 1906 to divert water from Jett and Copper creeks over the Nugget divide. In 1906 the water was turned in from Copper Creek July 20 and from Jett Creek August 18, and was turned out September 25. The ditch carries the total flow of these creeks above the intake up to a maximum of about 10 second-feet. In 1907 a gage was established below Copper Creek and read by A. D. Jett.

Discharge measurements on Jett Creek ditch at outlet, 1906–7.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-ft.*	1906.	*Feet.*	*Sec.-ft.*
July 21		2.4	September 14		3.9
August 11		.8	1907.		
August 29		4.6	July 31	1.59	8.1
August 31		7.3	Do	1.38	5.3
September 2		9.2	Do	1.21	3.6
September 7		7.2	Do	.75	0.0
September 10		5.3			

Daily gage height and discharge of Jett Creek ditch, 1907.

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.59	8.1	1.50	6.9
2			1.50	6.9	1.50	6.9
3			1.45	6.2	1.50	6.9
4			1.40	5.6	1.45	6.2
5			1.35	5.0	1.45	6.2
6			1.33	4.8	1.45	6.2
7			1.33	4.8	1.45	6.2
8			1.33	4.8	1.50	6.9
9			1.25	3.9	1.60	8.2
10			1.25	3.9		0
11			1.25	3.9		0
12	1.15	3.0	1.25	3.9	1.60	8.2
13	1.35	5.0	1.30	4.4	1.60	8.2
14	1.32	4.6	1.30	4.4	1.60	8.2
15	1.15	3.0	1.30	4.4		
16	1.20	3.4	1.55	7.6		
17	1.15	3.0	1.50	6.9		
18	1.18	3.2	1.60	8.2		
19	1.19	3.3	1.60	8.2		
20	1.30	4.4	1.55	7.6		
21	1.42	5.9	1.50	6.9		
22	1.22	3.6	1.45	6.2		
23	1.32	4.6	1.45	6.2		
24	1.38	5.4	1.50	6.9		
25	1.40	5.6	1.50	6.9		
26	1.45	6.2	1.45	6.2		
27	1.45	6.2	1.50	6.9		
28	1.42	5.9	1.55	7.6		
29	1.45	6.2	1.55	7.6		
30	1.50	6.9	1.50	6.9		
31	1.59	8.1	1.50	6.9		
Mean		4.9		6.1		6.1

GRAND CENTRAL DITCH.

The completed portion of the Grand Central ditch diverted water from Nugget Creek at an elevation of 785 feet from June 27 to September 29, 1906, and from July 9 to October 2, 1907. In 1907 a gage was installed just below Nugget Creek and read by A. D. Jett. The entire flow of the creek was diverted except on September 11 and 12 and possibly a few other days of high water. For measurements during 1906 see page 50.

Discharge measurements of Grand Central ditch, 1907.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 9	1.39	5.4	July 9	1.18	1.27
Do	1.28	3.7	Do	1.47	6.6

Daily gage height and discharge of Grand Central ditch, 1907.

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.34	4.4	1.50	8.0
2			1.34	4.4	1.50	8.0
3			1.32	4.0	1.45	6.8
4			1.32	4.0	1.45	6.8
5			1.32	4.0	1.45	6.8
6			1.30	3.6	1.45	6.8
7			1.30	3.6	1.45	6.8
8			1.28	3.3	1.50	8.0
9	1.45	6.8	1.28	3.3	1.60	10.6
10	1.34	4.4	1.25	2.8	1.70	13.4
11	1.34	4.4	1.25	2.8		0
12	1.38	5.2	1.28	3.3		0
13	1.38	5.2	1.27	3.1	1.70	13.4
14	1.45	6.8	1.30	3.6	1.70	13.4
15	1.35	4.6	1.30	3.6	1.70	13.4
16	1.35	4.6	1.50	8.0	1.70	13.4
17	1.31	3.8	1.50	8.0	1.70	13.4
18	1.40	5.6	1.55	9.3	1.70	[illegible]
19	1.46	7.0	1.55	9.3	1.60	[illegible]
20	1.48	7.5	1.60	10.6	1.60	[illegible]
21	1.65	12.0	1.60	10.6	1.60	[illegible]
22	1.47	7.3	1.55	9.3	1.55	[illegible]
23	1.48	7.5	1.50	8.0	1.55	[illegible]
24	1.46	7.0	1.55	9.3	1.55	[illegible]
25	1.40	5.6	1.50	8.0	1.50	[illegible]
26	1.38	5.2	1.50	8.0	1.50	[illegible]
27	1.36	4.8	1.50	8.0		[illegible]
28	1.33	4.2	1.50	8.0		[illegible]
29	1.32	4.0	1.55	9.3		[illegible]
30	1.32	4.0	1.50	8.0		[illegible]
31	1.34	4.4	1.50	8.0		
Mean		5.7		6.2		[illegible]

DAVID CREEK DITCH.

David Creek enters Nome River from the east a short distance below the intake of the Miocene ditch. It has a well-sustained flow which is diverted at an elevation of about 590 feet by a ditch that discharges into Nome River just above the Miocene intake. In 1906 the water was running in this ditch before gagings were made on Nome River. Except during extreme high water, it carried the entire flow of David Creek up to its capacity of about 14 second-feet. When the ditch was cleaned out in 1907 it was enlarged from 4 feet to 5 feet on the bottom, increasing its capacity to nearly 20 second-feet. The gage was read by employees of the Miocene Ditch Company during August, 1906, and July to September, 1907.

Discharge measurements of David Creek ditch, 1906–7.

Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-ft.*
July 3		3.5
July 29		6.4
August 3		4.4
August 23	0.51	7.9
August 29	.41	5.4
Do	.49	7.6
Do	.63	10.1
Do	.78	13.7
August 29	0.81	13.7
Do	.68	11.4
1907.		
July 17	.50	8.9
July 25	.79	13.0
Do	.83	13.7
August 4	.69	11.5

Daily gage height and discharge of David Creek ditch, 1906-7.

[Drainage area at point of diversion, 4.3 square miles.]

Day.	1906.		1907.					
	August.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1					0.75	12.4	0.70	11.6
2					.70	11.6	.65	10.9
3					.80	13.2	.80	13.2
4	0.35	4.4			.69	11.5	.80	13.2
5	.35	4.4			.67	11.2	.72	11.9
6	.35	4.4			.62	10.5	.70	11.6
7	.42	5.8			.60	10.2	.68	11.3
8	.38	5.0			.56	9.6	.60	10.2
9	.37	4.8			.56	9.6	.60	10.2
10	.37	4.8			.52	9.1	.50	8.9
11	.38	5.0			.52	9.1	.55	9.5
12	.40	5.4			.52	9.1		0
13	.38	5.0			.52	9.1		0
14	.35	4.4			.50	8.9		0
15	.34	4.3			.50	8.9		0
16	.33	4.1			.80	13.2		0
17	.39	5.2	0.50	8.9	.82	13.5		0
18	.31	3.7	.52	9.1	.80	13.2	.90	14.9
19	.29	3.3	.50	8.9	.90	14.9	.99	16.5
20	.40	5.4	.60	10.2	.90	14.9	.85	14.0
21	.38	5.0	.60	10.2	.95	15.8	.85	14.0
22	.50	7.5	.60	10.2	.95	15.8	.73	12.1
23	.52	7.9	.80	13.2	.72	11.9	.68	11.3
24	.48	7.1	.80	13.2	.70	11.6		10.6
25	.54	8.3	.80	13.2	.72	11.9	.58	9.9
26	.77	13.2	.80	13.2	.72	11.9	.57	9.8
27	.34	4.3	.70	11.6	.75	12.4	.54	9.4
28	.40	5.4	.65	10.9	.75	12.4	.50	8.9
29	.41	5.6	.75	12.4	.75	12.4	.50	8.9
30	.78	13.4	.75	12.4	.75	12.4	.45	8.3
31	.80	13.8	.75	12.4	.75	12.4		
Mean		6.1		11.3		11.8		9.0

NOTE.—These discharges are believed to represent the total flow of the creek from August 3 to 20, 1906, and from about July 23 to September 8, and September 19 to 30, 1907.

SEEPAGE MEASUREMENTS ON MIOCENE DITCH.

Measurements were made at different times at several points along the main ditch and also on the Jett Creek branch to determine the loss by seepage from the different sections of the ditch. The discharge of the branches and principal feeders was found by measuring the flow in the ditch above and below them. The figures obtained for the section between points of measurement were therefore the resultant of the gain from creeks too small to measure and the loss by seepage and leakage. The measurements of July 3 to 4 and July 27 were made at periods of extreme low water, and show a much larger loss than those of September 11 to 12, when there was much more water entering. On the latter date the ditch was gaining along much of its course. These measurements are of value to ditch builders in showing the losses which may be expected in ditches in frozen countries.

Seepage measurements of Miocene ditch, 1906.

MAIN DITCH FROM NOME RIVER TO GLACIER CREEK.

Date.	Point of measurement.	Discharge.	Gain.	Loss.
		Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*
July 3	Nome River intake	21		
Do	Above Hobson	15.8		5.2
July 4	do	20.5		
Do	Below Hobson	31.0	10.5	
Do	Above flume	28.1		2.9
Do	Below flume	29.8	1.7	
Do	Above Ex	27.9		1.9
Do	Above tunnel	28.8	.9	
July 27	Nome River intake	28		
Do	Black Point	25.7		2.3
Do	Above Dorothy	26.2	.5	
Do	Below Dorothy	26.0		.2
Do	Above Hobson	23.7		2.3
Do	Below Hobson	38.0	14.3	
Do	Grouse Creek branch	1.7		
	Total above flume	39.7		
Do	Below flume	36.5		3.2
August 2	do	28.3		
Do	Glacier branch	13.0		
Do	Dexter branch	13.3		
	Total	26.3		2.0
September 11	Nome River at intake	29.8		
Do	Black Point	30.7	.9	
Do	Above Dorothy	30.3		.4
Do	Above Hobson	30		.3
Do	Below Hobson	44.4	14.4	
Do	Grouse Creek branch	2.4		
	Total above flume	46.8		
Do	Below flume	43.9		2.9
September 12	do	[a] 43		
Do	Glacier Fork at Ex	30.3		
Do	Dexter Fork at Ex	15.3		
	Total at Ex	45.6	2.6	
September 13	Glacier Fork at Ex	[a] 29.6		
Do	Above tunnel	29.4		.2
July 29	Intake, David Creek branch	6.9		
Do	Outlet, David Creek branch	6.4		.5

JETT CREEK BRANCH.

Date.	Point of measurement.	Discharge.	Gain.	Loss.
September 10	Copper Creek ditch, intake	2.5		
Do	Copper Creek ditch, outlet into Jett Creek ditch	1.8		0.7
Do	Jett Creek ditch, intake	4.2		
	Total	6.0		
Do	Jett Creek ditch, below junction with Copper Creek ditch	5.7		.3
Do	Outlet over Nugget divide	5.3		.4

[a] Estimated.

MISCELLANEOUS MEASUREMENTS.

The following measurements were made at the points stated during the two years:

Miscellaneous measurements of Miocene ditch, 1906-7.

Date.	Point of measurement.	Discharge.
1906.		*Sec.-ft.*
August 23	Above Dorothy Creek siphon	39.5
September 25	do	41.4
1907.		
July 2	Grouse Creek branch	11.7
July 20	Above Snow Gulch	31.9
July 31	Copper Creek branch	3.5
August 20	Above Dorothy Creek siphon	40.9
September 28	Grouse Creek branch	5.8

CAMPION DITCH AT BLACK POINT.

The Campion ditch diverts water from Buffalo Creek at an elevation of 610 feet. Its lower end terminates in Dorothy Creek, into which it discharges. The ditch has a width of 6 feet on the bottom and 9 feet on top, is 2 feet deep, and has a mean velocity of 2 feet per second when running full. The water was turned in at 1 p. m., July 6, 1906. The ditch broke near its outlet at 7 a. m., July 8. It was repaired and water turned in again on the 19th. All water was turned out from 9.30 p. m. August 12 to 2.30 p. m. August 13.

It ran continuously from July 7 to September 29, 1907, except September 23, when the water was turned out on account of slush ice.

Measurements were taken on the ditch in order to determine the natural flow of Nome River below the junction of Buffalo and Deep Canyon creeks.

Discharge measurements of Campion ditch at Black Point, 1906-7.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-ft.*	1907.	*Feet.*	*Sec.-ft.*
July 7	0.80	11.9	July 10	0.88	9.9
July 20	.60	8.9	July 12	.35	2.7
July 21	.70	10.2	July 17	.79	8.2
August 2	.67	9.7	August 4	1.04	13.9
August 11	1.36	27.5			
August 18	.76	12.0			
August 23	1.10	19.6			
August 31	1.00	16.8			

Daily gage height and discharge of Campion ditch, 1906–7.

[Drainage area at point of diversion, 8.2 square miles.]

Day.	1906.						1907.					
	July.		August.		September.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	......	....	0.69	10.1	0.98	16.5	......	....	1.00	12.8	1.10	15.7
2	......	....	.68	10.0	.90	14.5	......	....	1.00	12.8	1.12	16.3
3	......	....	.65	9.5	1.02	17.5	......	....	1.00	12.8	1.12	16.3
4	......	....	.62	9.0	1.04	18.0	......	....	.99	12.5	1.10	15.7
5	......	....	.56	8.2	1.00	17.0	......	....	.95	11.5	1.06	14.5
6	......	....	.61	8.9	1.02	17.5	......	....	.90	10.3	1.11	[illegible]
7	0.88	14.1	.69	10.1	.96	16.0	0.71	6.8	.92	10.8	1.08	15.1
8	......	....	.70	10.3	.96	16.0	.58	5.1	.96	11.8	1.06	14.5
9	......	....	.73	10.9	1.00	17.0	.80	8.3	.98	12.3	1.16	17.4
10	......	....	.77	11.7	1.08	19.0	.81	8.5	.90	10.3	.82	8.7
11	......	....	1.13	20.4	1.07	18.8	.66	6.0	.90	10.3	.65	5.9
12	......	....	1.05	18.2	1.02	17.5	.52	4.4	.94	11.3	.93	11.0
13	......	....	1.09	19.2	1.06	18.5	.77	7.8	.94	11.3	1.00	12.8
14	......	....	1.02	17.5	1.02	17.5	.69	6.5	.98	12.3	.91	10.5
15	......	....	.92	15.0	.98	16.5	.66	6.0	.89	10.1	.97	12.0
16	......	....	.80	12.3	.93	15.2	.73	7.1	1.08	15.1	.92	10.8
17	......	....	.80	12.3	.92	15.0	.70	6.7	.99	12.5	.97	12.0
18	......	....	.78	11.9	.90	14.5	.95	11.5	1.09	15.4	1.01	13.1
19	......	....	.75	11.3	1.10	19.5	.84	9.1	1.01	13.1	1.06	14.5
20	......	....	.80	12.3	.98	16.5	.90	10.3	.98	12.3	1.18	18.0
21	......	....	.76	11.5	.50	7.5	.94	11.3	1.03	13.6	.98	12.3
22	......	....	1.01	17.2	.60	8.7	.88	9.9	1.04	13.9	.99	12.5
23	......	....	1.16	21.3	.75	11.3	.93	11.0	1.02	13.4	......	0
24	......	....	.99	16.8	.72	10.7	.89	10.1	1.02	13.4	.98	12.2
25	.92	15.0	.93	15.2	.91	14.8	.88	9.9	1.00	12.8	.99	12.5
26	.78	11.9	1.15	21.0	.96	16.0	.89	10.1	1.09	15.4	1.06	14.5
27	.75	11.3	1.16	21.3	1.02	17.5	.83	8.9	1.08	15.1	1.04	13.9
28	.82	12.7	1.14	20.7	.98	16.5	.86	9.5	1.06	14.5	1.03	13.6
29	.78	11.9	1.09	19.2	.95	15.8	.91	10.5	1.05	14.2	.98	12.2
30	.76	11.5	1.00	17.0	.94	15.5	1.05	14.2	1.12	16.3	......	0
31	.72	10.7	.99	16.8	......	....	1.07	14.8	1.08	15.1	......	....
Mean	......	12.4	......	14.4	......	15.8	......	9.0	......	12.9	......	12.5

SEWARD DITCH.

The Seward ditch was built in 1905–6 to take water from Nome River just below Dorothy Creek, at an elevation of 407 feet, and convey it to Saturday Creek for use along the ancient beach line. Its total length is 38 miles. The water is conducted across Hobson and Clara creeks by 42-inch continuous stave-pipe siphons having lengths of 1,050 and 800 feet. A part of the flow of Hobson Creek is diverted by a branch ditch.[a] In 1907 a gage was established near the intake and read by the ditch walker.

Measurements to determine the flow and also the seepage of this ditch were made as follows:

Seepage measurements of Seward ditch, 1906.

Date.	Point of measurement.	Discharge.	Gain.	Loss.
		Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*
July 29	Intake	19.7		
Do	Above Clara Creek	20.6	0.9	
Do	Hobson branch	4.0		
		24.6		
Do	Above Trout Creek	22.0		2.6

---

[a] For measurements of the Hobson Creek branch, see page 24.

Other measurements were made at the intake as follows:

Discharge measurements of Seward ditch at intake, 1906–7.

Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-ft.*
August 18		25
August 30		26
September 13		[a] 32
1907.	*Feet.*	*Sec.-ft.*
July 11	0.55	19.1
July 18	.72	23.2
July 24	.82	25.7

[a] Computed from gage reading.

Daily gage height and discharge of Seward ditch at intake, 1907.

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.85	27.2	0.90	29.0
2			.85	27.2	.89	28.6
3			.85	27.2	.89	28.6
4			.80	25.4	.89	28.6
5			.74	23.6	.88	28.3
6			.72	23.0	.88	28.3
7			.71	22.8	.89	28.6
8			.72	23.0	.88	28.3
9			.74	23.6	.85	27.2
10			.72	23.0	.81	25.8
11	0.60	20.1	.72	23.0		0
12	.62	20.5	.71	22.8	.82	26.2
13	.65	21.3	.78	24.8	.85	27.2
14	.65	21.3	.77	24.5	.84	26.9
15	.70	22.5	.71	22.8	.84	26.9
16	.70	22.5	.88	28.3	.84	26.9
17	.70	22.5	.88	28.3	.85	27.2
18	0.70	22.5	0.85	27.2	0.85	27.2
19	.75	23.8	.84	26.9	.82	26.2
20	.75	23.8	.84	26.9	.82	26.2
21	.75	23.8	.90	29.0	.78	24.8
22	.75	23.8	.84	26.9	.78	24.8
23	.75	23.8	.87	27.9	.80	25.4
24	.75	23.8	.87	27.9	.80	25.4
25	.80	25.4	.90	29.0	.80	25.4
26	.82	26.2	.90	29.0	.80	25.4
27	.82	26.2	.85	27.2	.80	25.4
28	.88	28.3	.85	27.2	.75	23.8
29	.82	26.2	.87	27.9	.74	23.6
30	.85	27.2	.89	28.6	.75	23.8
31	.85	27.2	.89	28.6		
Mean		23.9		26.2		25.7

PIONEER DITCH.

The Pioneer ditch, begun in 1905 and completed in 1907, has its intake on Nome River just below the mouth of Christian Creek, about 3 miles below the Seward intake and at an elevation of about 330 feet. It has a total length of 38 miles and extends to Anvil Creek. There are three siphons, composed of two lines of 30-inch riveted steel pipes—one 545 feet long across Hobson Creek, one 1,050 feet long across Banner Creek, and one 755 feet long across Dexter Creek. Several narrow gulches and gullies eroded by waste water from the other ditches are crossed by flumes.

Daily gage heights and discharges of the Pioneer ditch at the intake and of Nome River are given on page 22.

GRAND CENTRAL RIVER DRAINAGE BASIN.

GENERAL DESCRIPTION.

On account of its elevation and well-sustained flow, Grand Central River offers one of the most valuable unused water supplies of Seward Peninsula. The drainage area of this stream, which is about 12 miles long and 2 miles wide, is almost surrounded by ridges of the Sawtooth Range (Kigluaik Mountains), having elevations of 1,500 to 4,000 feet. (See Pl. VI, *A* and *B*.)

The river is formed near the foot of Mount Osborn, at an elevation of about 700 feet, by the junction of North and West forks, and flows in a southerly direction into Salmon Lake. From the forks to Salmon Lake the river has a fall of about 300 feet, and at high stages spreads over a wide gravelly bed. On either side there is a little bottom land, from which the mountains rise abruptly.

The principal tributaries of Grand Central River below the forks are Gold Run and Rainbow Creek from the east, and Thompson, Thumit, Nugget, Jett, and Morning Call creeks from the west. These tributary streams, with the exception of Nugget Creek, drain short, steep-sided gulches. They have considerable fall and are fed from melting snow.

In order to make the water from this drainage basin available for use at Nome it has to be diverted over the Nugget divide, which has an elevation of 785 feet. One such diversion has been made from Jett Creek and Copper Creek, from which water is taken by the Jett Creek ditch into the Miocene ditch.

The Miocene Ditch Company is building a ditch which will tap West Fork above the mouth of the Crater Lake outlet and North Fork at an elevation of about 850 feet. This ditch will extend down the west side of the valley, crossing and tapping Thompson and Thumit creeks, and will pass over the Nugget divide, where it will be taken up by the main Miocene ditch and carried to Glacier and Anvil creeks.

The Wild Goose Mining and Trading Company has started from Crater Lake a 42-inch continuous wood-pipe line, which will extend along the south side of the valley over the Nugget divide and down Nome Valley to Anvil Mountain. The company plans to dam and use Crater Lake as a storage resorvoir, into which the waters from North and West forks will be diverted by lateral pipes. Other laterals will carry the water of Gold Run and Thompson Creek into the main pipe line. Measurements made in this drainage are shown on the following pages.

NORTH FORK OF GRAND CENTRAL RIVER.

North Fork of Grand Central River rises in a cirque at the base of Mount Osborn, which is surrounded by almost perpendicular moun-

A. UPPER GRAND CENTRAL RIVER DRAINAGE.

B. MOUNT OSBORN, JULY, 1906.

tains rising from 1,000 to 3,000 feet above the bed of the stream. This cirque contains a small glacier, the melting of which maintains a very steady flow. The flow is increased by a large spring at an elevation of about 860 feet.

Discharge measurements on this stream in 1906 were made at elevations of about 750 feet and 1,030 feet, points which give the flow at the ditch and pipe intakes, respectively. The bed is very rough and it is difficult to obtain satisfactory measuring sections. Gage heights were read at the time of the measurements by measuring down from reference points on rocks.

In 1907 a gaging station was established about 100 yards above the junction of the forks to take the place of the one at the ditch intake. The increase in flow between the stations is small. The gage was read by Cornelius Edmunds.

Daily gage height and discharge of North Fork of Grand Central River near ditch intake, 1906.

[Elevation, 750 feet; drainage area, 5.4 square miles.]

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1		23		30		44
2		(23)		30	0.92	[b] 44
3		(23)		30		38
4		(25)		32		38
5				32		40
6				29		37
7			0.81	[b] 32		33
8				33		31
9				31	.76	[b] 27
10				33		28
11	1.10	[a] 67		32		27
12				27		(26)
13				27		26
14				28		27
15				28		26
16			.76	[a] 27		25
17			.74	[b] 25		25
18				27		27
19				25		
20		40		27		
21		(45)		(32)		
22	.85	[a] 38		(36)	1.5	[b] [c] 120
23		42		(60)		
24		61	.85	[b] 37		
25	.95	[a] 47		40		
26	.90	[b] 42		(40)		
27		45		(67)		
28		50		67		
29		38		71		
30		42		54		
31		28		48		
Mean		[d] 39.9		36.7		[e] 31.6
Run-off per square mile		7.39		6.80		5.85
Run-off depth in inches		4.67		7.84		3.92

[a] Measurements.
[b] Estimates based on gage readings.
[c] Not included in mean.
[d] 17 days.
[e] 18 days.

NOTE.—These values were obtained by subtracting the sum of the discharges at the West Fork and Crater Lake station from the flow below the forks. For the days for which this method does not give consistent results the discharges are based on the West Fork flow and are in parentheses. From July 5 to 19 the flow did not fall below 40 second-feet. The flow on June 26 was 43 second-feet.

Discharge measurements of North Fork of Grand Central River at the forks, 1907.

[Elevation 690 feet.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 8	1.31	65	August 13	1.07	[illegible]
July 16	1.19	41	August 26	1.36	[illegible]
July 25	1.23	47	September 6	1.18	[illegible]
July 26	1.20	45	September 16	1.44	[illegible]
August 5	1.11	34			

Daily gage height and discharge of North Fork of Grand Central River at the forks, 1907.

[Drainage area, 6.9 square miles.]

Day.	July.		August.		September.		Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.16	37	1.32	64	19		50	1.28	56	1.32	[illegible]
2			1.20	42	1.22	45	20		60	1.34	68	1.30	[illegible]
3			1.15	36	1.14	35	21		80	1.44	89	1.29	[illegible]
4			1.15	36	1.22	45	22		51	1.44	89	1.10	[illegible]
5			1.12	33	1.25	50	23		50	1.41	83	1.18	[illegible]
6			1.10	31	1.16	37	24		46	1.32	64		
7			1.10	31	1.10	31	25	1.22	45	1.30	60		
8	1.31	62	1.10	31	1.07	29	26	1.20	42	1.37	75		
9		46	1.10	31	1.50	102	27	1.19	41	1.38	77		
10	1.25	50	1.08	29	2.15	238	28	1.14	35	1.31	62		
11		70	1.10	31	2.10	194	29	1.11	32	1.74	152		
12		60	1.10	31	1.68	106	30	1.14	35	1.66	136		
13		65	1.08	29	1.52	72	31	1.16	37	1.42	85		
14		50	1.11	32	1.50	68	Mean		48.7		58.1		64.7
15		41	1.05	27	1.49	66	Run-off per square mile		7.06		8.42		9.38
16	1.19	41	1.34	68	1.44	57	Run-off, depth in inches		6.30		9.71		8.02
17		38	1.40	81	1.40	49							
18		42	1.35	70	1.37	45							

NOTE.—Channel conditions were changed during the high water of September 10, and a new rating table was used after that date. Discharges for days between July 8 and 25, when the gage was not read were obtained by the aid of a hydrograph.

Daily discharge in second-feet of North Fork of Grand Central River at pipe intake, 1906-7.

[Elevation, 1,030 feet; drainage area, 2.3 square miles.]

Day.	1906.			1907.		
	July.	Aug.	Sept.	July.	Aug.	Sept.
1	21	22	31		30	46
2	21	22	[a] 31		34	32
3	21	22	27		29	25
4	22	24	27		29	32
5		24	28		[a] 27	36
6		21	26		25	27
7		[a] 23	23		25	22
8		25	22	[a] 42	25	21
9		23	[a] 19	37	25	74
10		25	20	40	23	171
11		24	19	56	23	140
12		20	17	48	23	76
13		20	18	52	22	52
14		21	19	40	24	49

[a] Measurements. Other discharges are obtained by taking about the same percentage of the flow at the lower station, as was found on the dates of measurements. This varied from 70 to 90 per cent. Gagings on June 20, 1906, gave 30 second-feet, and on June 26, 1906, 43 second-feet. The flow from July 5 to 19, 1906, probably exceeded 35 second-feet.

Daily discharge in second-feet of North Fork of Grand Central River at pipe intake, 1906-7—Continued.

Day.	1906.			1907.		
	July.	Aug.	Sept.	July.	Aug.	Sept.
15	....	21	18	33	20	47
16	....	20	18	33	51	[a]41
17	....	[a]19	17	30	61	35
18	....	20	19	34	52	32
19	....	19	....	40	42	28
20	31	20	....	48	51	26
21	35	24	....	64	67	25
22	30	27	....	41	67	15
23	33	45	....	40	62	18
24	48	[a]28	....	37	48	....
25	37	30	....	37	[a]43	....
26	[a]33	30	....	[a]38	54	....
27	34	50	....	33	55	....
28	38	50	....	28	44	....
29	28	53	....	26	110	....
30	32	40	....	28	98	....
31	21	36	....	30	61	....
Mean	30.3	27.4	22.2	39.0	43.5	46.5
Run-off per square mile	13.2	11.9	9.65	16.9	18.9	20.2
Run-off, depth in inches	7.86	13.7	6.46	15.1	21.8	17.3

[a] Measurements. Other discharges are obtained by taking about the same percentage of the flow at the lower station, as was found on the dates of measurements. This varied from 70 to 90 per cent. Gagings on June 20, 1906, gave 30 second-feet, and on June 26, 1906, 43 second-feet. The flow from July 5 to 19, 1906, probably exceeded 35 second-feet.

A limestone spring at an elevation of 850 feet discharges into North Fork near the proposed ditch intake, and is the largest of a considerable number of springs in the upper Grand Central Valley. The following measurements of the flow of this spring were made in 1907: July 10, 3.8 second-feet; September 5, 7.4 second-feet.

WEST FORK OF GRAND CENTRAL RIVER.

West Fork of Grand Central River has its source in Mount Osborn, and flows between Mount Osborn and the high ridges which separate the Grand Central drainage from the Sinuk drainage. It is fed from snow storage for a greater part of the season, by limestone springs, and by Crater Lake, which lies at an elevation of 973 feet and has an area of about 106 acres.

There is considerable glacial drift in the lower part of the basin containing several depressions, one having an area of nearly 5 acres. These depressions fill with water during a rain and gradually drain off through the gravel.

Two gaging stations were established on the fork in 1906 at elevations of 1,010 and 860 feet. The lower station is just above the outlet to Crater Lake and shows the flow at the proposed ditch intake. The other station was established to obtain the flow at the proposed pipe intake by comparison with the flow at the lower station. The flow was about 70 per cent of that at the lower station during the earlier part of the season of 1906. As the snow above the pipe intake melted away and the flow of the springs between the intakes increased, this percentage became about 35 for low water and 50 for higher stages. The cold weather in September checked the flow at high levels and reduced the percentage to 32. During 1907 the percentages were almost the same as for the corresponding dates of 1906. In 1907 an additional station was established just above the forks, where the flow from Crater Lake is included.

Discharge measurements of West Fork of Grand Central River at the forks, 1907.

[Elevation, 690 feet.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
July 10	1.88	107
July 16	1.77	80
July 26	1.74	77
August 5	1.65	50
August 13	1.61	46
August 26	1.71	61
September 5	1.62	44
September 17	1.70	61

NOTE.—These measurements were made by subtracting the flow of North Fork from that of the river below the forks, taking both from the rating curves of the two stations, all three gages being read at the same time.

Daily gage height and discharge of West Fork of Grand Central River at the forks, 1907.

[Drainage area, 7.7 square miles.]

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.72	66	1.82	93
2			1.71	64	1.78	82
3			1.70	61	1.63	47
4			1.70	61	1.72	66
5			1.65	50	1.68	57
6			1.60	42	1.68	57
7			1.60	42	1.76	77
8	1.93	129	1.62	45	1.84	99
9		95	1.64	48	2.07	179
10	1.88	112	1.62	45	2.70	406
11		125	1.62	45	2.37	287
12		90	1.65	50	2.12	197
13		95	1.62	45	1.82	93
14		88	1.65	50	1.80	87
15		80	1.62	45	1.80	87
16	1.77	79	1.88	112	1.74	71
17		70	2.00	154	1.70	61
18		75	1.92	125	1.67	54
19		85	1.88	112	1.62	45
20		100	1.78	82	1.61	44
21		140	1.82	93	1.59	41
22		90	1.78	82	1.54	34
23		80	1.72	66	1.61	44
24		76	1.65	50		
25	1.75	74	1.64	48		
26	1.75	74	1.63	47		
27	1.70	61	1.64	48		
28	1.65	50	1.65	50		
29	1.60	42	2.32	276		
30	1.68	57	2.38	291		
31	1.70	61	1.88	115		
Mean		84.5		81.0		100
Run-off, per square mile		11.0		10.5		13.0
Run-off, depth in inches		9.82		12.1		11.1

Discharge measurements of West Fork of Grand Central River at ditch intake, 1906-7.

[Elevation, 860 feet.]

Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-ft.*
June 19		40.4
June 26		38
July 1		28.6
July 10	1.65	115
July 11	1.53	86
July 22	1.20	38.1
July 24	1.41	58
July 25	1.34	50
August 6	1.12	30.9
August 16	1.01	23
1907.	*Feet.*	*Sec.-ft.*
July 8	1.30	69
July 16	1.18	51
July 26	1.13	44
August 6	1.01	32
August 25	1.18	35
September 5	1.18	39
September 16	1.37	48

Daily gage height and discharge of West Fork of Grand Central River at ditch intake, 1906–7.

[Elevation, 860 feet; drainage area, 5.4 square miles.]

Day.	1906.						1907.					
	July.		August.		September.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	......	29	1.12	30	1.27	44	......	....	......	45	1.20	41
2	1.10	28	......	30	1.24	40	......	....	......	44	1.25	47
3	1.00	22	......	30	1.20	36	......	....	......	43	1.10	31
4	1.10	28	......	34	1.12	30	......	....	......	43	1.15	36
5	1.80	162	......	34	1.08	27	......	....	1.08	39	1.15	36
6	......	....	1.12	30	1.05	25	......	....	1.06	37	1.15	36
7	......	....	1.15	32	1.05	25	......	....	1.08	39	1.12	33
8	......	....	1.11	29	1.02	23	1.30	69	1.15	47	1.10	31
9	......	....	......	26	1.01	23	......	65	1.15	47	1.35	61
10	1.65	116	1.02	23	1.00	22	1.51	107	1.09	40	1.85	149
11	1.53	86	1.05	25	1.00	22	......	110	1.10	41	1.75	109
12	1.75	144	1.10	28	1.00	22	......	65	1.10	41	1.60	84
13	1.60	103	1.08	27	.98	21	......	68	1.12	43	1.45	59
14	1.55	90	1.05	25	.95	20	......	60	1.12	43	1.40	52
15	1.45	70	......	24	.92	19	......	54	1.07	38	1.40	52
16	1.40	61	1.01	23	.92	19	1.18	51	1.49	103	1.37	48
17	1.45	70	1.00	22	.92	19	......	45	1.48	77	1.32	42
18	1.40	61	1.00	22	1.00	22	......	50	1.38	60	1.30	40
19	1.30	47	1.00	22	......	....	......	60	1.25	43	1.28	38
20	1.30	47	.98	21	......	....	......	70	1.35	56	1.28	38
21	1.35	54	1.12	30	......	....	......	100	1.40	63	1.27	37
22	1.20	36	1.20	36	1.60	[a]103	......	65	1.35	56	1.22	32
23	1.52	83	1.39	60	......	....	......	58	1.25	43	......	35
24	1.41	63	1.21	37	......	....	......	54	1.20	37	......	....
25	1.33	51	1.16	33	......	....	1.20	54	1.18	35	......	....
26	1.25	42	1.22	38	......	....	1.13	45	1.19	36	......	....
27	1.25	42	1.35	54	......	....	......	42	1.20	37	......	....
28	......	39	1.30	47	......	....	......	34	1.18	35	......	....
29	1.20	36	1.30	47	......	....	......	28	1.50	98	......	....
30	1.15	32	1.27	44	......	....	1.10	41	1,48	82	......	....
31	1.14	31	......	44	......	....	......	45	1.38	66	......	....
Mean		62.0	......	32.5	......	25.5	......	60.0	......	50.2	......	50.7
Run-off per square mile		11.5	......	6.02	......	4.72	......	11.1	......	9.30	......	9.39
Run-off. depth in inches		11.5	......	6.94	......	3.16	......	9.90	......	10.7	......	8.03

[a] Not included in mean.

NOTE.—Discharges for 1907 have been computed from four rating tables on account of the shifting channel conditions, and are somewhat uncertain. Discharges for days between July 8 and August 5, when the gage was not read, were obtained by the aid of a hydrograph.

Daily gage height and discharge of West Fork of Grand Central River at pipe intake, 1906–7.

[Elevation, 1,010 feet; drainage area, 2.8 square miles.]

Day.	1906 (discharge).			1907.					
	July.	August.	September.	July.		August.		September.	
				Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Feet.*	*Sec.-ft*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	[a] 19	12	22				14		13
2	18	12	19				14		15
3	15	12	16				14		15
4	18	14	12				14		11
5		14	9				12	.88	[b] 11.5
6		[a] 12	9			0.86	[a] 11.3		11
7		12	8				12		12
8		10	8		31		15		13
9		9	[a] 7.3		29		15		20
10		8	7	1.27	[a] 47		13		74
11	[a] 45	9	7		48		13		54
12	72	11	7		29		13		40
13	52	10	7		30	.91	[b] 13.7		28
14	45	9	6		26		14		25
15	32	8	6		24		12		25
16	27	8	6		22		52	1.02	[b] 23
17	32	[a] 7.6	6		20		35		17
18	27	8	7		22		19		13
19	20	8			26		14		12
20	20	7			31		18		12
21	23	12			44		20		12
22	[a] 15	16			29		18		10
23	44	30			26		14		11
24	32	[a] 18.5			24		12		
25	[a] 25	15			24	.90	[a] 12		
26	19	19		[a] .98	[a] 19.3		12		
27	19	27			18		12		
28	16	24			15		11		
29	14	24			12		39		
30	13	22			18		33		
31	12	22			20		26		
Mean	27.0	13.9	9.4		26.4		17.6		20.5
Run-off per square mile	9.64	4.96	3.36		9.43		6.29		7.32
Run-off, depth in inches	8.96	5.72	2.25		8.42		7.25		6.26

[a] Measurements.

[b] Estimates based on gage readings. Other discharges are obtained by taking about the same percentage of the flow at elevation 860 feet as was found on the dates of measurements. Gagings on June 19, 1906, gave 28 second-feet, and on June 26, 26 second-feet.

CRATER LAKE OUTLET.

Crater Lake discharges into West Fork of Grand Central River just below the ditch intake on that stream. The lake, which lies in a depression of glacial origin, has an elevation of 973 feet and an area of 106 acres. Its basin adjoins those of Sinuk River and Thompson Creek.

A gaging station was located on the outlet about midway between the lake and West Fork. The stream bed is composed of large angular rocks and has a fall of nearly 300 feet to the mile. It is hard to make measurements on account of the swiftness of the current, and the highest one of 1906 is only approximate. Gage heights were taken by employees of the Wild Goose Mining and Trading Company.

Discharge measurements of Crater Lake outlet, 1906–7.

[Elevation, 925 feet.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-ft.*	1907.	*Feet.*	*Sec.-ft.*
June 19		14.2	July 8	1.32	36.5
June 26		23.7	July 16	1.18	21.1
July 1		13.6	July 26	1.13	16.7
July 10	1.55	59.0	July 30	1.04	13.7
July 22	.96	12.0	August 6	1.00	10.0
July 24	1.10	21.5	August 13	.99	10.6
August 6	.90	7.1	August 25	.95	8.0
August 8	.98	13.0	September 5	.93	7.5
August 16	.80	5.6			
September 9	.73	4.3			

Daily gage height and discharge of Crater Lake outlet, 1906–7.

[Drainage area, 1.8 square miles.]

Day.	1906.						1907.					
	July.		August.		September.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1		14	0.85	7	0.98	13				20	1.03	11.8
2	1.00	14		7	.94	10				20	1.10	16.0
3	1.00	14		8	.90	9				17	1.08	14.7
4	1.15	25		8	.82	6				17	1.15	19.7
5	1.65	69		9	.78	5			1.04	12.3	.93	7.4
6			.90	9	.78	5			1.03	11.8	.90	6.4
7			.95	11	.78	5			.95	8.0	.85	5.2
8			.96	12	.75	4.5	1.32	36	1.03	11.8	.83	4.8
9				10	.73	4.3		28	1.02	11.2	.80	4.2
10	1.55	59	.90	9	.71	4.1	1.27	31	1.02	11.2	1.05	12.8
11	1.25	33	.90	9	.69	3.9		36	1.03	11.8	1.90	106
12	1.45	50	1.00	14	.68	3.8		26	1.02	11.2	1.75	88
13	1.30	37	.95	11	.65	3.5		30	1.04	12.3	1.40	46
14	1.15	25	.90	9	.65	3.5		26	1.04	12.3	1.40	46
15	1.10	21		7	.61	3.1		22	1.01	10.7	1.35	40
16	1.15	25	.80	5.5	.61	3.1	1.18	22	1.41	47	1.00	10.2
17	1.10	21	.80	5.5	.61	3.1		20	1.40	46	.97	8.9
18	1.05	17	.79	5.5	.75	4.5		22	1.30	34	.95	8.0
19	1.00	14	.80	5.5				26	1.20	24	.94	7.7
20	1.00	14	.78	5				30	1.35	40	.92	7.0
21	1.05	17	1.01	15				40	1.40	46	.82	4.6
22	.96	12	1.01	15	1.40	[a] 46		30	1.35	40	.75	3.5
23	1.06	18	1.22	31				24	1.30	34	.75	3.5
24	1.10	21	1.02	15				22	1.35	40		
25	1.05	17	1.00	14			1.17	21	.95	80		
26	1.02	15	1.10	21			1.13	18.2	1.36	41		
27	1.00	14	1.12	23				18	1.37	42		
28		12	1.10	21				15	1.35	40		
29	.90	9	1.05	17				12	1.45	52		
30	.88	8	1.00	14			1.04	12.3	1.35	40		
31	.88	8		13				17	1.30	34		
Mean		22.3		11.8		5.2		24.4		26.0		21.0
Run-off per square mile		12.4		6.56		2.89		13.6		14.4		11.7
Run-off, depth in inches		12.4		7.56		1.93		12.1		16.6		10.0

[a] Not included in mean.

GRAND CENTRAL RIVER BELOW THE FORKS.

This station was established to obtain the total flow that can be diverted over the Nugget divide from the headwaters of Grand Central River. But little water enters the stream between this station and the proposed ditch intakes. Gage readings were taken during 1906 by employees of the Wild Goose Mining and Trading Company. Gage readings were discontinued in 1907, but measurements were made and the discharge of West Fork obtained by subtracting that of North Fork from the total below the junction. The two stations above the forks replaced the one below the forks in 1907.

Discharge measurements of Grand Central River below the forks, 1906-7.

[Elevation, 680 feet.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-feet.*	1907.	*Feet.*	*Sec.-feet.*
July 1	0.95	63	July 10	1.33	145
July 11	1.40	180	July 16	1.20	121
July 24	1.29	140	July 26	1.19	119
Do	1.22	129	August 5	1.02	85
July 26	1.10	101	August 13	.97	72
August 7	.89	66	September 5	1.06	89
August 17	.79	54.4			

Daily gage height and discharge of Grand Central River below the forks, 1906.

[Drainage area, 14.6 square miles.]

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
1	0.95	63	0.90	67	1.10	100
2	.90	56	.90	67	1.05	91
3	.95	63	.90	67	1.00	82
4	1.05	80	.95	74	.95	74
5	1.87	370		74	.93	72
6			.90	67		67
7			.98	79		63
8			.94	73		59
9	1.75	325	.90	67	.80	55
10	1.70	300		65		54
11	1.45	198		66	.78	53
12		280		68	.75	50
13	1.45	198		65	.75	50
14	1.42	187		62	.75	50
15		168		59	.72	48
16		160	.81	56	.71	47
17	1.40	180	.79	54		47
18	1.10	100		54		54
19	1.05	91		53		
20	1.10	100	.78	53		
21	1.10	100		65		
22	1.00	82		59	1.72	[a]310
23	1.28	143		210		
24	1.29	145	1.08	96		
25	1.18	118	1.02	86		
26	1.10	100		140		
27		100		210		
28	1.10	100	1.25	135		
29	1.00	82	1.25	135		
30	1.00	82	1.15	111		
31	.90	67	1.12	104		
Mean		[b]144		85.2		[c]62.0
Run-off per square mile		9.86		5.84		4.25
Run-off, depth in inches		10.27		6.73		2.84

[a] Not included in mean. [b] 28 days. [c] 18 days.

NOTE.—The interpolated discharges of Aug. 21-23 and 26-27 are 40 to 45 per cent of the flow at the station below Nugget Creek. This is about the proportion that holds for higher water. Other interpolations are made by comparison with the West Fork and Crater Lake outlet stations.

GRAND CENTRAL RIVER BELOW NUGGET CREEK.

This station was established June 30, 1906, but it was not possible to obtain regular gage readings until August 12, after which the gage was read once each day by A. W. Peterson. At low water the river at this point is about 50 feet wide and 1 to 2 feet deep, and has a mean velocity of about 2 feet per second. It is impossible to obtain measurements above gage height 1.2 feet by wading. The estimates at this station give practically the total flow of Grand Central River into Salmon Lake.

Discharge measurements of Grand Central River below Nugget Creek, 1906.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
June 24	....	313	August 28	1.10	324
June 30	0.57	148	September 9	.46	121
July 7	.98	286	September 14	.36	101
August 4	.46	123			

Mean daily gage height and discharge of Grand Central River below Nugget Creek, 1906.

[Drainage area, 39 square miles.]

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
1	0.5	132	....	....	0.8	220
2	.45	120	....	....	.75	204
3	....	....	....	....	.65	172
4	....	....	....	....	.6	157
5	....	....	....	....	.6	157
6	....	....	....	....	.55	144
7	....	....	....	....	.5	132
8	....	....	....	....	.5	132
9	....	....	....	....	.45	120
10	1.9	750	....	....	.42	114
11	....	....	....	....	.4	109
12	1.55	545	0.5	132	.4	109
13	....	....	.5	132	.38	105
14	....	....	.5	132	.35	100
15	....	....	.4	109	.35	100
16	....	....	.42	114	.3	90
17	....	....	.45	120	.3	90
18	....	....	.4	109	.4	109
19	....	....	.35	100	1.2	375
20	....	....	.5	132	2.6	1,230
21	.6	157	.55	144	2.2	950
22	....	....	.5	132	1.6	570
23	....	....	1.5	520	1.6	570
24	....	....	.8	220	1.35	445
25	....	....	.7	187	1.15	352
26	.5	132	1.05	310	....	....
27	....	....	1.5	520	....	....
28	....	....	1.1	330	....	....
29	....	....	.95	272	....	....
30	....	....	.9	255	....	....
31	....	....	.8	220	....	....
Mean	....	....	....	[a] 210	....	[b] 274
Run-off per square mile	....	....	....	5.38	....	7.03
Run-off, depth in inches	....	....	....	4.00	....	6.54

[a] 20 days.

[b] 25 days.

GOLD RUN.

Gold Run enters Grand Central River from the east, about 2 miles below the forks. It drains a high cirque which lies between North Fork and Fox Creek, has a rapid fall, and terminates in a large gravel fan. A glacial lake near the head of its valley affords possibilities of storage to regulate the flow. On account of the large flow and the concentration of a considerable fall in a short distance, Gold Run has greater advantages for a high-head power development than any other stream on the south side of the Kigluaik Mountains.

In order to determine the quantity of water from this stream available for diversion across the Nugget divide, a station was established at an elevation of about 800 feet.

Daily gage height and discharge of Gold Run, 1906-7.

[Elevation, 800 feet.]

Day.	1906.						1907.					
	July.		August.		September.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1		14		18		30				24		22
2		[a] 13		18	0.95	[b] 26				24		25
3		13		18		23				22		25
4		20		20		20				22		30
5				24		17			1.24	[b] 22	1.22	[b] 20
6				30		16				19		16
7			1.03	[b] 34		15				16		14
8			.90	[b] 22		14	1.57	[a] 72		18		13
9			.89	[b] 21		13		60		18		13
10				20	.71	[a] 12		80		15		25
11		52		20		12		86		15		120
12	1.21	[a] 69		24		12		65		15		90
13		55		22		11		70		15		70
14		45		20		11		60	1.16	[a] 16		60
15		40		18		11		48		13		50
16		38	.81	[b] 17		10	1.40	[b] 42		50	1.38	[a] 26
17		42	.80	[b] 16.5		10		38		55		24
18		24		16		12		42		48		22
19		20		16				48		40		20
20		22		15				54		60		18
21		23		28				70		75		14
22	.84	[a] 18.5		34				45		75		11
23	1.00	[b] 30		50				40		70		10
24		30		34				35		60		
25	1.00	[a] 30	.99	[b] 29				32		56		
26	.93	[b] 24		44				32	1.58	[b] 74		
27		24		68				24		76		
28		21	1.13	[a] 51				20		60		
29		20		40			1.20	[b] 18		90		
30		19		36			1.25	[a] 23		70		
31		18		32				24		40		
Mean		29.0		27.6		15.3		47.0		41.1		32.1

[a] Measurements.

[b] Estimates based on gage heights. Other discharges were obtained by plotting a hydrograph passing through the known points and following the rise and fall of the other streams in the vicinity. Gagings made on June 20, 1906, gave 22 second-feet and on June 25, 24 second-feet.

THOMPSON CREEK.

Thompson Creek enters Grand Central River from the west about 2 miles below the forks. It drains a small glacial cirque almost wholly surrounded by very steep walls ranging from 1,000 to 2,000 feet in height. Measurements were made at a point with an elevation of 720 feet, which gives the amount of water available for diversion over the Nugget divide.

Daily gage height and discharge of Thompson Creek, 1906–7.

[Elevation, 720 feet; drainage area, 2.5 square miles.]

Day.	1906.						1907.					
	July.		August.		September.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1		11		9		19				30		16
2		[a] 11		9		14				27		17
3		11		10		12				23		16
4		16		10		8				20		22
5				11		7				15		12
6				15		7			1.24	[b] 13	1.14	[a] 9.6
7			1.39	[b] 22.5		7				9		8
8			1.22	[b] 14		6	1.55	[a] 49		13		7
9			1.19	[a] 12.5	1.00	[b] 6.2		45		13		7
10				11	1.00	[a] 6.2	1.69	[b] 82		13		15
11		36		11		6		87		13		100
12		[a] 52		17		6		60		13		80
13		40		14		6		50	1.24	[b] 13		50
14		30		12		5		40	1.34	[a] 20		50
15		24		11		5		34		15		42
16		28	1.11	[b] 9.6		5	1.45	[b] 32		50		14
17		23	1.12	[b] 10		5		30		50	1.25	12.6
18		19		10		6		34		39		11
19		16		10				40		29		10
20		16		9				46		40		9
21		18		20				55		46		6
22	1.20	[b] 13		20				44		40		5
23		21		40				35		34	.99	[b] 5
24	1.42	[a] 25	1.40	[b] 23				30		40		
25	1.41	[a] 23		21			1.42	[b] 28	1.15	[b] 9		
26	1.29	[b] 17.5		28			1.47	[b] 35	1.47	[b] 35		
27		16		30				34		35		
28		14		28				31		35		
29		11	1.44	[b] 25.4				27		40		
30		11		22			1.44	[a] 32		34		
31		10		20				34		30		
Mean		20.5		16.6		7.6		42.2		27.0		22.8
Run-off per square mile		8.20		6.64		3.04		16.9		10.8		9.12
Run-off, depth in inches		7.62		7.66		2.10		15.1		12.4		7.80

[a] Measurements.

[b] Estimates based on gage heights. Other discharges were obtained by plotting a hydrograph passing through the known points and following the rise and fall of Crater Lake outlet, whose basin adjoins that of Thompson Creek and is of a similar character. A measurement on June 25 gave 42 second-feet.

NUGGET AND COPPER CREEKS.

Nugget Creek rises in the divide between Nome River and Grand Central River and empties its waters and those of its tributary, Copper Creek, into Grand Central River about 2 miles above Salmon Lake.

The headwaters of both Nugget and Copper creeks are precipitous and are fed by springs in limestone. Measurements were made on Nugget Creek at an elevation of 785 feet, at the point where its waters are diverted over the Nugget divide by the Grand Central branch of the Miocene ditch.

During 1907 the discharge of the creek was measured in the ditch about 200 feet below the intake. The results of measurements are given on page 31.

The flow of Copper Creek is also tapped by a branch of the Jett Creek ditch at an elevation of about 800 feet. The combined monthly discharge of Copper and Jett cree' . for 1907 is given on page 51.

Discharge measurements of Nugget and Copper creeks, 1906-7.

NUGGET CREEK.

[Elevation, 785 feet.]

Date.	Elevation of point of measurement.	Discharge.	Date.	Elevation of point of measurement.	Discharge.
1906.	*Feet.*	*Sec.-feet.*	1906.	*Feet.*	*Sec.-feet.*
June 18		1.8	August 11		3.[illegible]
June 19		1.6	August 29		8.0
June 21		4.4	September 2		6.8
June 28		.96	September 7		[illegible]
July 12		6.8	September 14		4.4

COPPER CREEK.

Date.	Elevation of point of measurement.	Discharge.	Date.	Elevation of point of measurement.	Discharge.
1906.			1906.		
June 18	700	3.8	August 31	800	6.6
June 19	800	8.7	September 10	800	2.4
June 21	700	11.6			
July 12	700	11.3	1907.		
July 21	800	2.4	July 9	800	9.4
August 11	800	.8			

Monthly discharge of Nugget Creek at Miocene intake, 1907.

[Drainage area, 2.1 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Sec.-ft. per sq. mile.	Depth in inches.
July 9-31	12.0	3.8	5.7	2.71	2.32
August	10.6	2.8	6.2	2.95	3.40
September	40	6.8	11.0	5.24	5.85
84 days	40	2.8	7.8	3.71	11.57

NOTE.—The maximum for September is estimated. For the daily discharge see page 32.

JETT CREEK.

Jett Creek enters Grand Central River from the south. It has a short drainage basin and is made up of a series of falls and rapids. Water is diverted over the Nugget divide into Nome River by the Jett Creek ditch. (See p. 31 for measurements on Jett Creek ditch.)

The discharge of this ditch at times of low water is equal to the combined discharge of Jett and Copper creeks at the intakes, less a small amount of loss by seepage. This has been compared with the natural flow of Nome River for four such periods, as follows:

Comparison of flow of Jett Creek ditch and Nome River at Miocene intake, 1907.

Dates.	Nome River.	Jett and Copper creeks.	Creeks in per cent of Nome River.
	Sec.-ft.	*Sec.-ft.*	
July 26-31	30	7.0	23
August 1-16	22	5.2	24
August 19-25	32	7.0	22
September 3-8	34	6.4	19

The above table shows that the discharge of Jett and Copper creeks was from 24 to 19 per cent of that of Nome River.

The combined discharges of the two creeks for other periods than those given have therefore been taken as 24 per cent of that of Nome River for July, 20 per cent for August, and 16 per cent for September, on the assumption that in September the flow was checked to a greater extent by cold weather than that of Nome River.

Measurements were made in 1906 to show the amount of water available at the diversion.

Discharge measurements of Jett Creek, 1906.

[Elevation, 800 feet.]

Date.	Discharge.	Date.	Discharge.
	Sec.-ft.		*Sec.-ft.*
June 19	14.9	July 21	5.8
July 2	4.4	August 31	8.3
July 12	14.3	September 10	4.2

Combined monthly discharge of Jett and Copper creeks at Miocene intake, 1907.

[Drainage area, 2.25 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Sec.-ft. per sq. mile.	Depth in inches.
July	40	5.9	17.3	7.69	8.87
August	15	3.9	7.1	3.16	3.64
September	49	2.9	9.6	4.27	4.76
92 days	49	2.9	11.3	5.04	17.27

MORNING CALL CREEK.

Morning Call Creek enters Grand Central River from the south near Salmon Lake. The hills to the south are lower and more exposed than those of Copper and Jett creeks, and the snow melts earlier in the spring. At low water all the flow disappears in the pervious limestone above the point where a ditch intended to cross the Nugget divide would have its intake. The water appears again near the contact with the schist, at an elevation of about 750 feet.

Discharge measurements of Morning Call Creek, 1906.

Date.	Elevation of point of measurement.	Discharge.	Date.	Elevation of point of measurement.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
June 20	700	36	July 2	700	[illegible]
June 20	900	24.6	July 12	700	[illegible]
June 24	500	27.3	August 9	900	[illegible]

STORAGE POSSIBILITIES.

There are several reservoir sites in the headwaters of Grand Central River. The most important of these is Crater Lake, which lies in a cirque at an elevation of 973 feet. This lake has an area of 106 acres, and a dam to raise the water 15 feet would increase the area to about 160 acres. The outlet could be arranged so as to draw the lake 5 feet below its present level, thus giving a storage capacity of about 2,500 acre-feet. There is also a small lake at the head of Gold Run. Its area has not been measured, but it would probably afford sufficient storage to reenforce the low-water flow of that stream considerably.

Computations have been made to ascertain the storage capacity that would be necessary to maintain a given discharge in a proposed ditch, taking water either from (1) Gold Run, both forks of Grand Central River, and Thompson Creek; (2) the forks of Grand Central River and Thompson Creek, without Gold Run; or, (3) Gold Run alone, with storage obtained on the lake on that stream. Both 1 and 2 have been studied for a discharge of 80, 100, and 120 second-feet with storage obtained on Crater Lake.

The amount of water that would have to be drawn from storage during any day is the difference between the discharge of the streams tapped and the assumed capacity of the ditch. The sum of these deficiencies for any week or month gives the total draft that would be made on the reservoirs for that period.

The days of deficient flow during 1906 occurred in four periods and those for 1907 in three periods, between which there were periods when the discharge of the streams exceeded the capacity of the ditch. During such periods of greater flow some of the water could be conserved in one of the lakes already mentioned. The amount thus retained would be equal to the excess of the discharge of the streams over the ditch capacity until this excess became greater than the discharge into the lake, or until the lake had refilled or contained enough water to meet any later demands on it. The amount thus conserved during periods of high water, deducted from the total drawn from storage, gives the net storage capacity that would be required. The unit used in the following statement is 1 second-foot for 1 day, which is equal to nearly 2 acre-feet.

Storage capacity required to maintain given discharges, 1906 and 1907.

GRAND CENTRAL RIVER, THOMPSON CREEK, AND GOLD RUN.

Discharge.	July 1 to September 30, 1906.			July 8 to September 23, 1907.		
	Total deficiency.	Storage capacity required.		Total deficiency.	Storage capacity required.	
Sec.-feet.	*Sec.-ft. for 1 day.*	*Sec.-ft. for 1 day.*	*Acre-feet.*	*Sec.-ft. for 1 day.*	*Sec.-ft. for 1 day.*	*Acre-feet.*
80	127	123	244	9	9	18
100	560	372	738	51	51	101
120	1,332	1,002	1,987	274	145	288

GRAND CENTRAL RIVER AND THOMPSON CREEK.

80	413	268	532	26	26	51
100	1,227	925	1,834	212	107	213
120	2,206	1,811	3,590	607	320	635

GOLD RUN.

20	165	104	206	91	40	79
25	395	181	359	225	117	232
30	679	444	880	410	217	430

Note.—Discharges for the latter part of September, 1906, were estimated.

SALMON LAKE.

Salmon Lake lies at the foot of the Kigluaik Mountains at an elevation of about 442 feet. It has a water surface area of 1,800 acres and a drainage area of 81 square miles. Its principal supply comes from Grand Central River, which enters it at its west end. A number of small streams also enter the lake from both the north and the south, but with the exception of Fox Creek and Jasper Creek these are of minor importance. The outlet of the lake is through Kruzgamepa River.

This lake offers an excellent opportunity for a storage reservoir for power purposes and mining along Kruzgamepa River. The use of its water in the vicinity of Nome is practically prohibited, owing to its low elevation and the long tunnel which would be necessary to bring the water through the Nugget divide into the Nome River basin. By raising the water of the lake to an elevation of 500 feet the shortest tunnel line would be between 5 and 6 miles long; and if any allowance be made for drawing on the storage, water could not be brought through to the Nome Valley at an elevation greater than about 450 feet. The mouth of the tunnel would be near Dorothy Creek, and the loss in grade between that point and Nome would bring the water so low that it could not be used to any extent for hydraulicking. Even if the water could be brought to the vicinity of Nome under a sufficient head for hydraulicking, the great cost and difficulty of building so long a tunnel would make the feasibility of the plan very doubtful.

Measurement of flow in and out of Salmon Lake, 1906.

Date.	Stream.	Discharge
		Sec.-feet.
June 22	Rainbow Creek	34
Do.	Fox Creek	[illegible]
Do.	8 small streams from north	[illegible]
June 24	Jasper Creek	11
Do.	Morning Call Creek	27
Do.	Jett Creek	a 10
Do.	6 small streams from south	a 4
Do.	Grand Central River below Nugget Creek	313
	Total	474
June 23	Kruzgamepa River, at outlet of Salmon Lake	425

a Estimated.

NOTE.—The stage of Salmon Lake remained practically constant from June 22 to 24, inclusive.

A measurement on Fox Creek August 16, 1906, gave a discharge of 17.3 second-feet.

KRUZGAMEPA RIVER DRAINAGE BASIN BELOW SALMON LAKE.

GENERAL DESCRIPTION.

Kruzgamepa or Pilgrim River, the outlet of Salmon Lake, has a larger discharge than any other stream in this section on which records have been obtained. For about 12 miles it flows in a valley ranging from 6 to 12 miles in width, and then enters the lowlands north of the Kigluaik Range, finally discharging into Imuruk Basin. The principal tributaries are Crater, Grouse, and Homestake creeks from the north and Iron Creek from the south.

As it leaves Salmon Lake the river flows through a narrow outlet having a width of 150 feet at the bottom and 500 feet at the top, offering an excellent dam site and location for a hydro-electric power plant. Plans for the construction of such a plant have been perfected by the Salmon Lake Power Company, which intends to develop 3,000 horsepower, to be used on dredges at Nome and Council and on Solomon River.

Salmon Lake, at its present level, 442 feet, covers 1,800 acres; if raised to a level of 475 feet it would cover 3,600 acres; and at 500 feet, 4,600 acres. The reservoir thus formed could be used for the storage of the water of the floods caused by the melting snow in the spring and the occasional heavy rains in the summer. The water thus retained would give a large minimum flow not only in summer but also during the winter months, when the natural run-off becomes small.

Kruzgamepa River seldom freezes over before the first of January, and it is probable that with proper installation power could be developed throughout the year.

KRUZGAMEPA RIVER AT OUTLET OF SALMON LAKE.

A gaging station was established at Leland's camp, about 100 yards below Salmon Lake, June 23, 1906. A temporary gage had been set and float measurements made during the spring flood by J. P. Samuelson.

Discharge measurements were made by wading when the discharge was less than 600 second-feet. The high-water measurements were made by floats in 1906, and from a cable in 1907.

The gage was read twice daily by J. P. Samuelson and M. Donworth.

Discharge measurements of Kruzgamepa River at outlet of Salmon Lake, 1906–7.

	Area of section.	Mean velocity.	Gage height.	Discharge.		Area of section.	Mean velocity.	Gage height.	Discharge
1906.	*Sq. ft.*	*Ft. per sec.*	*Feet.*	*Sec.-ft.*	1907.	*Sq. ft.*	*Ft. per sec.*	*Feet.*	*Sec.-ft.*
June 23	183	2.32	1.22	425	June 16	415	4.94	2.97	2,050
June 29	170	2.08	1.00	353	June 17	367	4.47	2.56	1,640
June 30	157	2.01	.93	315	June 28	282	3.62	1.88	1,020
July 9	431	5.43	3.18	2,340	Do	270	3.67	1.78	991
Do	412	5.09	3.02	2,094	July 2	248	3.03	1.56	751
July 10	372	4.73	2.68	1,760	July 4	220	2.58	1.30	567
August 4	117	1.81	.38	212	July 14	229	2.69	1.37	616
August 15	116	1.80	.37	209	August 2	149	2.04	.65	304
August 25	148	2.11	.70	312	August 14	125	1.86	.39	232
August 26	159	2.33	.80	371	August 23	174	2.52	.89	438
August 28	184	2.49	1.02	458	September 6	155	2.13	.68	330
September 1	164	2.27	.85	373	September 11	362	4.20	2.52	1,520
September 7	127	1.95	.52	248	September 12	327	4.01	2.19	1,310
September 17	108	1.62	.27	175	September 20	162	2.21	.76	358
September 21	336	4.61	2.38	1,546					
September 23	299	3.76	2.06	1,124					
September 24	269	3.44	1.80	925					

Daily gage height and discharge of Kruzgamepa River at Salmon Lake, 1906.

[Drainage area, 81 square miles.]

Day.	May.		June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			3.05	1,780	0.82	272	0.48	239	0.86	387
2			3.75	2,270	72	241	.42	221	.81	364
3			3.90	2,350	.70	235	.38	209	.74	336
4			4.20	2,520	.70	235	.36	203	.69	316
5			3.75	2,270	.80	265	.38	209	.65	300
6			3.20	1,920	1.10	380	.38	209	.60	280
7			2.45	1,220	1.10	380	.40	215	.53	256
8					1.92	1,030	.40	215	49	242
9					3.05	2,130	.40	215	.46	233
10					2.60	1,640	.36	203	.41	218
11					2.20	1,275	.35	200	.39	212

Daily gage height and discharge of Kruzgamepa River at Salmon Lake, 1906—Continued.

[Drainage area, 81 square miles.]

Day.	May.		June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
12					1.95	1,065	0.35	200	0.37	[illegible]
13					1.85	985	.36	203	.34	[illegible]
14					1.55	768	.34	197	.31	[illegible]
15					1.45	702	.36	202	.30	[illegible]
16					1.25	582	.35	200	.28	[illegible]
17					1.12	511	.32	197	.26	[illegible]
18					1.08	490	.30	185	.27	[illegible]
19					.98	441	.26	175	.52	[illegible]
20					.90	405	.32	191	1 34	[illegible]
21					.82	369	.39	212	2.35	[illegible]
22					.85	382	.42	221	2.40	[illegible]
23			1.20	420	.82	369	.66	304	2.11	[illegible]
24			1.25	442	.85	382	.71	324	1.78	[illegible]
25			1.20	420	.82	369	.70	320	1.58	[illegible]
26			1.12	388	.80	360	.76	344	1.38	[illegible]
27			1.10	380	.72	328	.90	405	1.22	[illegible]
28	5.45	3,270	1.05	360	.70	320	1.02	460	1.08	[illegible]
29	5.00	3,000	1.02	348	.62	288	1.05	475	.98	[illegible]
30	4.05	2,430	.92	308	.55	262	.99	446	.88	[illegible]
31	3.60	2,180			.50	245	94	423		
Mean		2,720		a 2,050 b 383		571		259		[illegible]
Run-off per square mile		33.6		a 25.3 b 4.73		7.05		3.20		[illegible]
Run-off, depth in inches		5.00		a 6.59 b 1.41		8.13		3.69		[illegible]
Run-off, acre-feet		21,000		a 28,500 b 6,040		35,100		15,900		[illegible]

a June 1 to 7. b June 23 to 30.

NOTE.—The channel changed during the high water of July 9, and a new rating table was used after that date. The discharges of May 28 to June 7 are based on measurements which show a low velocity, probably caused by backwater.

Daily gage height and discharge of Kruzgamepa River at Salmon Lake, 1907.

[Drainage area, 81 square miles.]

Day.	June.		July.		August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.70	875	0.69	326	1.14	522	0.30	[illegible]
2			1.58	791	.65	312	1.00	450	.23	[illegible]
3			1.44	696	.62	302	.90	405	.21	[illegible]
4			1.28	599	.61	298	.82	373	.20	[illegible]
5			1.20	555	.60	295	.77	354	19	[illegible]
6			1.20	555	.55	280	.73	340		
7			a1.50	735	.48	259	62	302		
8			a1.45	702	.45	250	.58	289		
9			a1.40	670	.45	250	.71	334		
10			a1.35	640	.44	247	1.25	582		
11			a1.30	610	.44	247	2.50	1,560		
12			a1.25	582	.42	241	2.26	1,330		
13			a1.30	610	.40	235	1.98	1,090		
14			1.35	640	.40	235	1.59	798		
15	3.30	2,360	1.26	588	.38	229	1.40	670		
16	2.99	2,040	1.15	528	.40	235	1.26	588		
17	2.47	1,530	1.10	500	.69	326	1.10	500		
18	2.72	1,770	1.02	460	.94	423	.98	441		
19	3.02	2,070	1.00	450	.97	436	.86	389		
20	2.80	1,850	1.00	450	.90	405	.74	344		
21	2.32	1,390	1.18	544	.88	397	.72	337		
22	2.08	1,180	1.18	544	.90	405	.62	302		
23	2.00	1,110	1.12	511	.89	401	.54	277		
24	2.08	1,180	1.08	490	.82	373	.54	277		

a Estimated.

Daily gage height and discharge of Kruzgamepa River at Salmon Lake, 1907—Continued.

Day.	June.		July.		August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
25	2.22	1,300	1.05	475	0.78	358	0.50	265		
26	2.30	1,370	1.02	460	.80	365	.48	259		
27	2.28	1,350	.98	441	.88	397	.46	253		
28	2.12	1,210	.80	365	.84	381	.42	241		
29	1.95	1,070	.72	337	.86	389	.38	229		
30	1.78	935	.62	302	1.18	544	.34	217		
31			.60	295	1.20	555				
Mean		1,480		548		335		477		187
Run-off per square mile		18.3		6.77		4.14		5.89		2.31
Run-off, depth in inches		10.9		7.80		4.77		6.57		.43
Run-off, acre-feet		47,000		33,700		20,600		28,400		1,850

NOTE.—The datum of the 1907 gage was 0.16 foot higher than that of the 1906 gage. The river began to break up May 22, 1907. The discharge increased up to June 15, which was the maximum of the season, and was probably as great during the first half of June as during the last half.

CRATER CREEK.

Crater Creek is the first large tributary entering Kruzgamepa River from the north. It rises in mountains that reach an elevation of nearly 4,000 feet. The topography and general character of its basin closely resemble those of Grand Central River. (See p. 38.) It drains many small lakes, but none of any considerable size. This stream has good possibilities for water-power development. Measurements were made at an elevation of about 550 feet.

Should developments in the vicinity of Nome ever demand it, the water of Crater Creek could be diverted over the divide into Eldorado River by about 8 miles of ditch and 1.2 miles of siphon across Kruzgamepa River, none of which would be under a pressure of more than 100 feet.

Discharge measurements of Crater Creek, 1906–7.

[Elevation, 550 feet.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-feet.*	1907.	*Feet.*	*Sec.-feet.*
August 5		67	June 29	1.80	217
August 15	0.45	57	July 3	1.55	131
August 27	1.30	290	July 15	1.56	141
September 1	.71	110	August 2	1.34	89
September 8	.45	55	August 23	1.66	185
September 16	.35	39	September 12	2.05	245

IRON CREEK.

Iron Creek rises in an area of limestone and schist hills of no great elevation lying between Salmon Lake and the headwaters of Casadepaga and Eldorado rivers. It is formed by the junction of Eldorado and Telegram creeks. Its principal tributaries are Discovery and Canyon creeks, both from the southwest. The portion of the stream above Discovery Creek is sometimes called Dome Creek. Iron Creek empties into Kruzgamepa River about 12 miles below Salmon Lake.

Several mines are being worked successfully on this stream and its tributaries. During 1906 the Gold Beach Development Company built a ditch 13 miles long, which diverts water from Eldorado, Discovery, and Canyon creeks, for use on Discovery, No. 1, and No. 2 claims on Iron Creek.

During 1907 gaging stations were established on Dome Creek below the junction of Eldorado and Telegram creeks, and on Iron Creek below the mouth of Canyon Creek. The gages were read during the low-water period in August by employees of the Gold Beach Development Company.

Measurements on Iron Creek and tributaries, 1906.

Date.	Stream.	Elevation.	Discharge.
		Feet.	*Sec.-feet.*
August 14	Iron Creek	450	[a] 17.1
September 15	do	425	[a] 26.1
August 14	Iron (Dome) Creek	630	6.0
September 15	do	630	5.0
August 13	Eldorado Creek	750	4.5
September 15	do	750	5.6
August 13	Discovery Creek	740	1.25
September 15	do	740	2.3
August 13	Canyon Creek	760	1.3
September 15	do	760	1.1

[a] Below Canyon Creek.

Discharge measurements of Dome and Iron creeks, 1907.

DOME CREEK.

[Elevation, 630 feet.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*
August 1	0.41	[illegible]
August 22	.48	[illegible]
September 18	.37	[illegible]

IRON CREEK BELOW CANYON CREEK.

[Elevation, 450 feet.]

August 1	2.09	[illegible]
August 22	[a] 1.50	[illegible]
September 19	[a] 1.38	[illegible]

[a] New gage.

Daily gage height and discharge of Dome and Iron creeks, August, 1907.

Day.	Dome Creek (drainage area, 20 square miles).		Iron Creek below Canyon Creek (drainage area, 50 square miles).	
	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	0.40	25	2.10	52
2	.39	24	2.10	52
3	.38	23	2.10	52
4	.37	22	2.10	52
5	.34	20	2.08	50
6	.31	18	2.08	50
7	.30	17	2.08	50
8	.27	15	2.05	47
9	.24	14	2.02	43
10	.22	13	2.00	41
11	.20	12	1.90	33
12	0.22	13	1.90	33
13	.26	15	1.90	33
14	.26	15	1.90	33
15	.28	16	2.00	41
16	.55	54	2.18	62
17	.70	101	2.45	100
Mean		24.5		48.5
Run-off per square mile		1.22		.99
Run-off, in inches		.77		.61

NOTE.—These discharges are very uncertain, as no measurements were obtained covering the low stages.

MISCELLANEOUS MEASUREMENTS.

Slate and Willow creeks are tributaries of Kruzgamepa River from the south, 5 or 6 miles below Salmon Lake. Rock Creek is a branch of Slate Creek. These streams will be tapped at an elevation of about 900 feet by a ditch which is being built to work ground on the left bank of Iron Creek. Measurements were made at the proposed intakes.

Pass, Smith, and Grand Union creeks rise on the north side of the Kigluaik Mountains, north of Grand Central River and Gold Run. They are fed by the melting of large banks of snow and have a very steep slope. A project is contemplated for bringing their waters to Coffee and Dahl creeks by means of a pipe line about 18 miles long across the flats of Kruzgamepa and Kuzitrin rivers to Coffee Dome.

Miscellaneous measurements in Kruzgamepa River drainage basin, 1907.

Date.	Stream.	Elevation.	Discharge.
		Feet.	*Sec.-feet.*
July 29	Pass Creek	620	18.1
Do	Smith Creek	890	40
Do	Grand Union Creek	650	12.7
September 19	Willow Creek	900	3.3
Do	Slate Creek	900	11.3
Do	Rock Creek	900	9.0

IMURUK BASIN DRAINAGE.

The following measurements were made on streams tributary to Imuruk Basin to determine their availability and value for water-power development. They rise on the northerly slope of the northernmost ridge of the Kigluaik Range and are fed by large banks of perpetual snow.

Measurements on streams tributary to Imuruk Basin, 1906.

Date.	Stream.	Elevation.	Drainage area.	Discharge.
		Feet.	*Sq. miles.*	*Sec.-feet.*
September 5	Fall Creek	1,208	5	34
Do	Glacier Creek	1,212	3	10
Do	Snow Gulch	1,212	2	9.7

SINUK RIVER DRAINAGE BASIN.

GENERAL DESCRIPTION.

Sinuk River rises on the southern slope of the Kigluaik Range, adjacent to the headwaters of Grand Central River and Thompson and Buffalo creeks. It flows in a southwesterly direction, entering Bering Sea near Cape Rodney. The upper portion of its drainage basin is mountainous, the greater part of it having an elevation of over 1,000 feet. The upper valley contains a large amount of glacial débris and rock slide. Below the mouth of Stewart River, which is the principal tributary, the valley widens out and is almost flat. The principal tributaries to the upper stream are Windy Creek and the outlet of Glacial Lake from the north and Stewart River from the south.

During 1906 only a few measurements were made and no daily discharge has been computed. A fair estimate of the weekly flow is given on page 72. During 1907 more measurements were made and additional gage readings obtained.

Three plans by which the water from this drainage basin could be brought into the Nome River Valley are outlined in Water-Supply Paper No. 196, pages 38–40. The development of such projects would be very expensive on account of the rocky nature of the ground in the Sinuk drainage basin and the great length of ditch required. The Grand Central River and its tributaries, with their low-water flow reenforced by storage, will probably furnish as much additional water supply as the development of the Nome region will require, and at a smaller cost than that at which it could be obtained from Sinuk River and Windy Creek. If a large body of ground adapted to hydraulic mining should be discovered in the Sinuk Basin itself, the river will furnish a good supply of water at a high level.

UPPER SINUK RIVER.

The gagings on the upper Sinuk during 1906 and prior to August, 1907, were made at an elevation of 770 feet, and show the probable water supply which could be diverted into Nome River. During August and September, 1907, the gaging station was located about 1½ miles farther downstream, at an elevation of about 700 feet.

Discharge measurements of upper Sinuk River, 1906.

[Elevation, 770 feet; drainage area, 6.2 square miles.]

Date.	Discharge.	Date.	Discharge.
	Sec.-feet.		*Sec.-feet.*
June 27	33	August 3	20
July 6	37	August 10	23.5
July 20	36		

Daily gage height and discharge of upper Sinuk River, 1907.

[Elevation, 700 feet; drainage area, 8.2 square miles.[a]]

Day.	July.	August.		September.		Day.	July.	August.		September.	
	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.		Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Sec.-ft.	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	[b] 70	......	36	......	55	20	80	......	46	......	32
2	60	......	35	1.38	[d] 46	21	100	......	54	......	24
3	54	......	34	......	40	22	60	......	54	1.21	[e] 7
4	40	......	31	......	50	23	56	1.34	[d] 37	......	......
5	48	......	29	......	40	24	48	......	34	......	......
6	[b] 52	......	26	1.32	[d] 33	25	42	......	32	......	......
7	46	......	24	......	30	26	38	......	50	......	......
8	42	1.28	[c] 26	......	28	27	[b] 36	......	62	......	......
9	42	......	25	......	60	28	29	1.40	[c] 55	......	......
10	60	......	25	......	160	29	24	......	80	......	......
11	80	......	24	......	114	30	28	......	100	......	......
12	70	1.27	[d] 24	......	90	31	32	......	70	......	......
13	[b] 75	......	24	......	75						
14	62	......	24	1.48	[c] 65	Mean	52.3	......	45.0	......	53.7
15	52	......	22	......	58						
16	44	......	60	......	52	Run-off per square mile	8.44	......	5.49	......	6.55
17	40	......	100	......	46						
18	50	......	82	1.41	[b] 41	Run-off, depth in inches	9.73	......	6.33	......	5.36
19	60	1.49	[c] 70	......	35						

[a] Elevation, 770 feet, and drainage area, 6.2 square miles during July.
[b] Measurement at elevation, 770 feet.
[c] Measurement at elevation, 700 feet.
[d] Computed from gage reading.
[e] Estimated; slush ice running.

NOTE.—Other discharges were obtained by plotting a hydrograph passing through the known points and following the rise and fall of Nome and Grand Central rivers.

WINDY CREEK.

Windy Creek, the first large tributary of Sinuk River, lies between the main ridge of the Kigluaik Mountains and the headwaters of the Sinuk. It adjoins West Fork of Grand Central River, from which it may be reached by crossing a high divide. The topography is very rough, the creek being entirely lost in some places in the large bowlders which form its bed.

Discharge measurements of Windy Creek, 1906.

Date.	Elevation at point of measurement.	Discharge.
	Feet.	*Sec.-ft.*
June 21	1,000	49
June 27	1,100	17
July 13	[a] 650	114
July 20	650	48
August 3	650	32
August 10	650	[b] 35
September 6	650	[b] 32

[a] Drainage area, 12 square miles. [b] Estimated.

Daily gage height and discharge of Windy Creek, 1907.

[Elevation, 650 feet; drainage area. 12 square miles.]

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	1.36	[a] 128		60		72
2		96		56	1.15	[a] 67
3		90		52		56
4		100		50		64
5		112		42		54
6		120		34	1.05	[a] 43
7		116		32		38
8		114	1.01	[b] 35		36
9		120		34		80
10		130		34		200
11		140		32		140
12		125	1.00	[a] 33		110
13	1.36	[b] 128		33		90
14		105		33	1.20	[a] 79
15		85		32		70
16		74		90		64
17		66		125		56
18		70		100	1.08	[a] 50
19		80	1.21	[b] 88		45
20		100		60		40
21		130		70		30
22		80		72		[c] 15
23		76	1.06	[a] 45		
24		72		42		
25		68		40		
26		60		68		
27	1.13	[b] 57		80		
28		48	1.14	[b] 70		
29		40		90		
30		50		120		
31		56		82		
Mean		91.5		59.2		68.1
Run-off per square mile		7.62		4.93		5.68
Run-off, depth in inches		8.78		5.68		4.65

[a] Computed from gage reading. [b] Measurements. [c] Estimated; slush ice running.

NOTE.—Other discharges were obtained in the same manner as those of Sinuk River.

NORTH STAR CREEK.

North Star Creek lies between Sinuk River and Windy Creek, and is a tributary to the latter near its mouth. It is a small stream with a steep slope.

Discharge measurements of North Star Creek, 1906.

[Elevation, 900 feet; drainage area, 2.3 square miles.]

Date.	Discharge.
	Sec.-ft.
June 27	9.8
July 6	18.1
July 13	16.4
July 20	3.9
August 3	3.0
August 10	2.9

Daily gage height and discharge of North Star Creek, 1907.

[Elevation, 900 feet; drainage area, 2.3 square miles.]

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	1.36	[a] 28	......	8	......	7
2	......	20	......	7	0.92	[b] 4.5
3	......	16	......	7	......	4
4	......	13	......	6	......	7
5	......	14	......	5	......	6
6	1.26	[a] 16	......	5	.94	[b] 4.8
7	......	14	......	4	......	4
8	......	13	0.94	[a] 4.8	......	4
9	......	14	......	5	......	4
10	......	16	......	5	......	40
11	......	20	......	5	......	30
12	......	22	.97	[b] 5.3	......	20
13	1.33	[a] 23	......	5	......	14
14	......	17	......	5	1.08	[b] 7.8
15	......	14	......	5	......	7
16	......	12	......	15	......	7
17	......	10	......	25	......	6
18	......	13	......	16	1.00	[b] 5.7
19	......	17	1.10	[a] 8.3	......	5
20	......	24	......	7	......	4
21	......	30	......	8	......	3
22	......	20	......	8	.75	[c] 2.0
23	......	16	97	[b] 5.2	......	......
24	......	13	......	5	......	......
25	......	10	......	4	......	......
26	......	8	......	8	......	......
27	1.03	[a] 5.5	......	12	......	......
28	......	5	1.13	[a] 9.1	......	......
29	......	4	......	14	......	......
30	......	5	......	20	......	......
31	......	6	......	10	......	......
Mean		14.8	......	8.3	......	8.9
Run-off per square mile		6.43	......	3.61	......	3.87
Run-off, depth in inches		7.41	......	4.16	......	3.16

[a] Measurements. [b] Computed from gage reading. [c] Estimated; slush ice running.

NOTE.—Other discharges were obtained in the same manner as those of Sinuk River.

STEWART RIVER.

Stewart River lies south of upper Sinuk River, to which it is tributary. It drains an area of limestone and schist hills. The flow is small and the stream of minor importance.

Discharge measurements of Stewart River, 1906.

[Elevation, 400 feet.]

Date.	Discharge.	Date.	Discharge.
	Sec.-ft.		*Sec.-ft.*
July 15	72	July 30	[a] 26
July 17	49	August 19	11.4

[a] Estimated.

SLATE CREEK.

Slate Creek is the second tributary to Stewart River from the north. The following measurements give approximately the flow that can be diverted into Nome River over Divide Creek:

Discharge measurements of Slate Creek, 1906.

[Elevation, 700 feet; drainage area, 2.1 square miles.]

Date.	Discharge.	Date.	Discharge.
	Sec.-ft.		*Sec.-ft.*
July 15	6.7	July 30	2.8
July 17	4.4	August 19	2.2

OTHER SINUK RIVER DRAINAGE.

For measurements on Josie, Irene, and Jessie creeks, which are small tributaries of Stewart River, see "Cedric ditch."

CRIPPLE RIVER DRAINAGE BASIN.

GENERAL DESCRIPTION.

Cripple River enters Bering Sea about 12 miles west of Nome, and drains an area of about 88 square miles. As yet but little mining has been done in this section, except in the vicinity of Oregon and Hungry creeks. Some small ditches have been constructed at the headwaters of Cripple River, the principal one being the Cedric, which diverts water from the Stewart River drainage area.

CEDRIC DITCH.

GENERAL DESCRIPTION.

The Cedric ditch was built in 1905 to divert water from Josie and Jessie creeks (tributary to Stewart River) over the divide to the Cripple River basin for use on Oregon, Hungry, Trilby, and Nugget creeks. After passing the divide it picks up water from upper Oregon (two forks), Slate, and Aurora creeks, which are its principal feeders, and from Daisy Swift Creek, Snowshoe Gulch, and three other small gulches. It has a total length of about 19 miles and a width of 4 to 8 feet. The elevation of the head is about 870 feet and of the outlet 790 feet. The capacity of the lower half is about 25 second-feet. Water is carried across Oregon Creek near the outlet by a syphon 2,970 feet long, of 30-inch riveted steel pipe. There are about 6 miles of distributing ditches at the lower end.

The following measurements were made to determine the amount of water available for the ditch:

Water available for Cedric ditch, 1906–7.

Stream.	1906.			1907.
	July 15–17.	July 30–31.	August 19.	August 31.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
Josie Creek	3.0	1.5	1.1	[a]2.0
Irene Creek	1.0	[a].8	[a].4	[a]3.0
Jessie Creek	[b]3.2	2.6	.6	[a]3.0
Upper Oregon Creek	[b]6.8	2.6	....	[a]3.5
Slate Creek	4.0	2.0	....	3.1
Aurora Creek	4.8	2.1	....	2.4
Daisy Swift Creek	.5	....	....	....
Total available for ditch	18.3	11.6	....	17.0

[a] Estimated.

[b] Measured below ditch level; only about half this amount is available for the ditch.

Seepage measurements on Cedric ditch, 1906.

Date.	Point of measurement.	Discharge.	Loss.	Distance.	Loss per mile.
		Sec.-ft.	*Sec.-ft.*	*Miles.*	*Sec.-ft.*
July 30	Below upper Oregon Creek	2.6			
Do	Above Slate Creek	1.9	0.7	2.3	0.3
Do	Below Slate Creek	3.9			
July 31	Above Aurora Creek	3.1	.8	1.8	.4
Do	Below Aurora Creek	5.2			
Do	Above Daisy Swift Creek	4.7	.5	2.0	.25
Do	Below Daisy Swift Creek	4.5	.2	.6	.3
Do	At penstock	2.5	2.0	3.7	.5
			4.2	10.4	.4

CEDRIC DITCH ABOVE PENSTOCK.

This station was established to determine the total flow of the ditch. The gage was located just above the penstock of the siphon across Oregon Creek. Part of the water was used in a giant connected with the bottom of the siphon and part was used for hydraulicking about one-fourth mile above the siphon.

Discharge measurements of Cedric ditch above penstock, 1907.

Date.	Above penstock.		Discharge to upper giant.
	Gage height.	Discharge.	
	Feet.	*Sec.-ft.*	*Sec.-ft.*
July 22	0.80	10.3	3.0
August 30	.78	8.6	4.4
August 31	.76	7.9	5.0
September 19	.10	0	

Daily gage height and discharge of Cedric ditch above penstock, 1907.

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.00	13.1	0.95	12.2
2			1.02	13.5	.85	10.2
3			1.02	13.5	.98	12.7
4			1.05	14.0	.88	10.8
5			.95	12.2	.95	12.2
6			.88	10.8	.95	12.2
7			.80	9.3	.98	12.7
8			.92	11.6	.95	12.2
9			.90	11.2	1.05	14.0
10			.90	11.2	1.20	16.9
11			.88	10.8	1.25	17.8
12			.90	11.2	1.15	16.0
13			.95	12.2	1.05	14.0
14			.98	12.7	1.02	13.5
15			.98	12.7	1.10	15.0
16			1.05	14.0	1.02	13.5
17			1.05	14.0	1.05	14.0
18			1.08	14.6	1.05	14.0
19			1.15	16.0		0
20			1.08	14.6		0
21			1.10	15.0		0
22	0.80	9.3	1.10	15.0		0
23	.88	10.8	.95	12.2	.65	6.6
24	1.00	13.1	.95	12.2	.68	7.1
25	.98	12.7	1.05	14.0	.60	5.7
26	1.00	13.1	1.20	16.9	.60	5.7
27	.90	11.2	1.10	15.0	.62	6.1
28	.88	10.8	1.05	14.0	.58	5.4
29	1.00	13.1	1.00	13.1	.52	4.5
30	1.10	15.0	.85	10.2	.50	4.2
31	1.05	14.0	.80	9.3		
Mean.		12.3		12.9		9.6

PENNY RIVER DRAINAGE BASIN.

GENERAL DESCRIPTION.

Penny River rises about 13 miles from the seacoast and enters Bering Sea about 10 miles west of Nome. Its basin lies between Snake and Cripple rivers and has a total area of 36 square miles. Two ditches have been built by the United Mining Company. The Sutton ditch has its intake one-half mile above the mouth of Willow Creek and extends about 6 miles to a point near the mouth of Jess Creek. The water is used for hydraulicking on the second beach line, which lies about 1,200 feet back of the present beach. The Highline ditch, uncompleted, has its intake 7 miles above the Sutton ditch and will extend to Sunset Creek, a distance of about 11 miles. The water is carried across Honey Creek in a pipe line 2,000 feet long.

PENNY RIVER AT SUTTON INTAKE AND SUTTON DITCH.

Gaging stations were established on Sutton ditch and Penny River just below the ditch intake, and the sum of the discharges gives the natural flow of the river at this point. The gages were read by employees of the United Mining Company.

Discharge measurements of Penny River and Sutton ditch at intake, 1906–7.

PENNY RIVER.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1906.	*Feet.*	*Sec.-ft.*	1907.	*Feet.*	*Sec.-ft.*
August 1		6.2	July 4	.82	12.6
			July 22	1.30	42
1907.			September 1	.99	16.3
July 4	1.11	31			

SUTTON DITCH.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1906.			1907.		
August 1		30	July 4	1.49	44
			July 22	1.11	25
1907.			September 1	1.32	38
July 4	1.20	28			

Daily gage height and discharge of Penny River and Sutton ditch at intake, 1907.

Day.	July.				August.				September.			
	River.		Ditch.		River.		Ditch.		River.		Ditch.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	......	71	......	29	......	85	......	0	1.0	19	1.3	35
2	......	56	......	29	......	85	......	0	1.0	19	1.3	35
3	......	41	......	29	......	85	......	0	1.0	19	1.3	35
4	1.1	26	1.2	29	......	85	......	0	1.0	19	1.3	35
5	1.1	26	1.2	29	......	85	......	0	.9	14	1.3	35
6	1.3	44	1.25	32	1.6	79	0.8	9	.9	14	1.3	35
7	2.2	152	1.2	29	1.4	55	.8	9	.9	14	1.3	35
8	1.6	79	1.2	29	1.1	26	1.0	18	.9	14	1.3	35
9	1.3	44	1.25	32	1.1	26	1.0	18	1.0	19	1.3	35
10	1.3	44	1.2	29	.8	10	1.2	29	2.1	140	1.3	35
11	1.3	44	1.2	29	.8	10	1.2	29	1.8	103	1.3	35
12	1.2	34	1.2	29	.7	7	1.2	29	1.6	79	1.3	35
13	1.4	55	1.2	29	.7	7	1.2	29	1.0	19	1 3	35
14	1.5	67	1.2	29	.7	7	1.2	29	1.0	19	1.3	35
15	1.2	34	1.1	23	.6	4	1.2	29	1.8	103	.5	0
16	1.2	34	1.1	23	1.4	55	1.2	29	1.8	103	.5	0
17	1.2	34	1 1	23	1.2	34	1.2	29	1.7	91	.8	9
18	1.2	34	1.1	23	1.1	26	1.2	29	1.3	44	1.3	35
19	1.5	67	1.1	23	.9	14	1.25	32	1 3	44	1 3	35
20	1.3	44	1.1	23	.8	10	1.3	35	1.3	44	1.3	35
21	1.5	67	1 1	23	1.0	19	1.25	32	1.3	44	1.3	35
22	1.3	44	1.1	23	.9	14	1.25	32	1.2	34	1.3	35
23	1.2	34	1.1	23	.8	10	1.3	35	1.1	26	1.3	35
24	1.4	55	1.1	23	.8	10	1.3	35	1.1	26	1.3	35
25	1.4	55	1.0	18	1.0	19	1.5	47	1.1	26	1.3	35
26	1.6	79	1.0	18	1.3	44	1.2	29	1.1	26	1.3	35
27	1.5	67	1.0	18	1.3	44	1.2	29	1.0	19	1.3	35
28	1.5	67	1.0	18	1.3	44	1 2	29	.9	14	1.3	35
29	1.4	55	.9	13	1.2	34	1.2	29	.9	14	1.3	35
30	1.5	67	.8	9	1.2	34	1.2	29	.8	10	1.3	35
31	1.6	79	.7	6	1.1	26	.1.2	29	......	......	......	......
Mean	......	54.8	......	23.9	......	35.3	......	23.8	......	33.9	......	31.8

Monthly discharge of Penny River at Sutton intake, 1907.

[Drainage area, 19 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Sec.-ft. per sq. mile.	Depth in inches.
July	181	55	78.7	4.14	4.77
August	88	33	59.0	3.11	3.58
September	175	45	71.1	3.74	4.17
92 days	181	33	69.6	3.66	12.52

NOTE.—These values are the sum of the discharges of Sutton ditch and of Penny River below the ditch intake.

Discharge measurements of Penny River at Highline intake, 1906-7.

Date.	Discharge.	Per cent of Sutton intake.	Date.	Discharge.	Per cent of Sutton intake.
1906.	*Sec.-ft.*		1907.	*Sec.-ft.*	
August 1	7.8	22	July 22	15.9	24
			August 30	15.6	28

SNAKE RIVER DRAINAGE BASIN.

GENERAL DESCRIPTION.

Snake River empties into Bering Sea at Nome. It has a drainage area of 110 square miles, which contains some of the richest mining ground in Seward Peninsula, notably the claims on Glacier, Anvil, and Little creeks. Owing to its slight fall the use of the main stream for mining purposes is limited to ground sluicing. All the available water from its tributaries is being used, and water is diverted into this area by the Miocene ditch, the Seward ditch, and the Nome River ditch of the Pioneer Mining Company.

SNAKE RIVER ABOVE GLACIER CREEK.

A station was established June 25, 1907, just above the mouth of Glacier Creek, to determine the discharge of this stream and the relation of the run-off from its drainage basin to that from areas in and near the Kigluaik Mountains. The run-off per square mile during the period covered by the records was 56 per cent of that of Nome River and 38 per cent of that of Kruzgamepa River.

The gage was read by A. H. Clambey.

Discharge measurements of Snake River above Glacier Creek, 1907.

Date.	Gage height	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
June 25	1.88	527	August 10	.89	72
July 3	1.20	168	September 3	1.01	112
July 20	1.13	147			

Daily gage height and discharge of Snake River above Glacier Creek, 1907.

[Drainage area, 69 square miles.]

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.35	235	1.05	120	1.08	129
2			1.30	212	1.02	111	1.05	120
3			1.25	191	1.00	105	1.05	120
4			1.18	163	1.00	105	1.05	120
5			1.22	178	.96	94	1.04	117
6			1.32	221	.95	91	1.03	114
7			1.50	308	.96	94	1.02	111
8			1.35	235	.94	89	1.08	129
9			1.25	191	.92	83	1.08	129
10			1.25	191	.92	83	1.15	152
11			1.28	204	.91	80	1.90	540
12			1.25	191	.90	77	1.68	418
13			1.20	170	.98	99	1.52	319
14			1.20	170	.97	97	1.47	293
15			1.18	163	.90	77	1.50	308
16			1.10	135	1.04	117		
17			1.12	142	1.10	135		
18			1.10	135	1.10	135		
19			1.18	163	1.06	120		
20			1.18	163	1.00	105		
21			1.20	170	1.05	120		
22			1.18	163	1.01	108		
23			1.16	156	.99	102		
24			1.22	178	1.00	105		

Daily gage height and discharge of Snake River above Glacier Creek, 1907—Continued.

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
25	1.90	540	1.30	212	1.02	111		
26	1.85	510	1.22	178	1.08	129		
27	1.80	480	1.18	163	1.10	135		
28	1.55	335	1.12	142	1.10	135		
29	1.45	283	1.08	129	1.10	135		
30	1.40	258	1.08	129	1.10	135		
31			1.05	120	1.08	129		
Mean		401		177		108		207
Run-off per square mile		5.81		2.56		1.56		3.00
Run-off, depth in inches		1.30		2.95		1.80		1.67

FLAMBEAU AND ELDORADO RIVER DRAINAGE BASINS.

Flambeau and Eldorado rivers rise near Salmon Lake and flow in a southerly direction to Bering Sea near Cape Nome.

The Flambeau Hastings ditch has its intake on the upper fork of Flambeau River and is to be built to Hastings Creek, near Cape Nome. Another ditch to Hastings Creek is projected, which will divert the water to Eldorado River below Venetia Creek, and will have a length of over 30 miles. The following measurements were made at the proposed intake of this ditch: August 14, 1906, 44 second feet; September 17, 1907, 225 second feet.

SOLOMON RIVER DRAINAGE BASIN.

Solomon River empties into Bering Sea at Solomon, 40 miles east of Nome. This stream has been a good producer of gold, and several ditches have been built to utilize its water and that of its tributaries, including the East Fork ditch of the Solomon River Hydraulic Company, the Midnight Sun ditch from Big Hurrah Creek, the Brogan ditch from the mouth of Johns Creek to East Fork, and a ditch about 7 miles long on Coal Creek.

A ditch has been started by the Three Friends Mining Company to furnish power for its dredge on Solomon River. It will take water from the river just below East Fork and extend to a point below the mouth of Shovel Creek, where a head of 75 feet will be available.

Discharge measurements in Solomon River drainage basin, 1907.

Date.	Stream and locality.	Drainage area.	Discharge.
		Sq. miles.	*Sec.-ft.*
October 1	Solomon River below Johns Creek	66	43
Do	Brogan ditch at intake		7.7
			50.7
October 2	Solomon River below East Fork	40	96
Do	East Fork ditch	10	17
			113

FLOW OF DITCHES IN NOME REGION.

The following table has been prepared to show in a concise manner the flow of the ditches which take their water supply from Nome River and its tributaries, and from near-by streams. It is also of value for comparison with the discharge of the streams from which the water is taken, to show the percentage of flow that can be delivered by a ditch at the point where it is to be used.

Monthly discharge of ditches in Nome region, 1907.

Ditch.	Point of measurement.	Yearly maximum.	July		August.	September.
		Sec.-ft.	*Days.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft*
Campion	Black Point	18.0	25	9.0	12.9	12.5
Miocene	do	42.6	29	28.0	34.4	[illegible]
Do	Clara Creek	37.0	29	25.4	28.7	[illegible]
Do	Above Hobson	34.9	29	23.6	27.4	[illegible]
Do	Below Hobson	54.7	31	43.8	45.3	47.9
Do	Flume	55.2	31	45.1	44.0	50.4
Do	David Creek branch	16.5	15	11.3	11.8	9.0
Do	Jett Creek branch	8.2	20	4.9	6.1	[illegible]
Do	Grand Central branch	13.4	23	5.7	6.2	9.0
Seward	Nome River intake	29.0	21	23.9	26.2	25.7
Do	Hobson Creek branch	....	26	5.2	4.3	4.5
Pioneer	Nome River intake[b]	26.8	16	20.4	22.2	[illegible]
Do	Hobson Creek branch	....	....	....	....	[illegible]
Sutton	Intake	35.0	31	23.9	23.8	[illegible]
Cedric	Penstock	17.8	10	12.3	12.9	9.6

[a] Mean for 14 days.
[b] Values for Pioneer ditch have been estimated at 85 per cent of those for Seward ditch; this was the proportion during the time for which records were obtained on both ditches.

AVAILABLE WATER SUPPLY DURING 1906 AND 1907.

In order to show the amount of water that was available during 1906 and 1907 for hydraulicking the placers near Nome, the mean flow of the streams in each drainage basin has been tabulated by weekly periods in the table on page 72. In using this table the following points should be noted :

The "Nome River high-level flow" represents the total amount of water in that river above the Miocene ditch, including the flow of the Campion ditch, David Creek, and Hobson Creek. The flow of the springs on Hobson creek has been taken as 14 second-feet during 1906 except for the first week in July, when it did not exceed 10 second-feet.

The "Nome River low-level flow" includes all additional water down to Pioneer ditch. The drainage area of Nome River below the Miocene and David Creek intakes and above the Pioneer intake is 18 square miles. The run-off from this area for the period in August, 1907, during which records were kept was at about the same rate per square mile as at the Miocene intake. The low-level flow has therefore been taken as 1.2 times the natural flow at the Miocene intake, where the drainage area is 15 square miles. To this has been added 60 per cent of the discharge of Hobson Creek at the Miocene intake, this being approximately the amount entering that stream between the Miocene and Pioneer intakes.

"Upper Grand Central River," etc., includes the station below the forks and those on Thompson Creek and Gold Run, and gives the amount that can be brought over the Nugget divide.

The mean flow of "Nugget, Copper, and Jett creeks" gives the amount that can be brought over the Nugget divide, and for 1906 was estimated from the few measurements obtained.

The flow of "Sinuk River, Windy and North Star creeks," has been estimated for an elevation of 800 feet, which is as low as the water can be taken over the divide into Nome River. The amount of this flow for 1906 was obtained by taking 70 per cent of the flow of Grand Central River below the forks, this precentage being determined as follows:

Comparison of flow of Grand Central River below forks with that of Sinuk River and its tributaries at elevation of 800 feet.

Date.	Sinuk River.	Windy Creek.	North Star Creek.	Total.	Grand Central below forks.	Sinuk, Windy, and North Star in per cent of Grand Central.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	
June 26, 27	33	22	10	65	105	62
July 6	37	(35)	18	90	....	....
July 13	(75)	86	16	177	198	89
July 20	36	36	4	76	100	76
August 3	20	24	3	47	67	70
August 10	23.5	26	3	52.5	65	81
September 6	(20)	24	(3)	47	67	70

The drainage area of Grand Central River lies on the north side of a ridge of the Kigluaik Mountains, and the basins of Sinuk River and Windy and North Star creeks lie adjacent to it on the south side of the same ridge. On the days when measurements of flow were made of the streams on both sides of the mountains it was found, as shown in the preceding table, that the flow on the south side was from 62 to 89 per cent of the flow on the north side. It is, therefore, conservative to say that the average combined flow of Sinuk River and Windy and North Star creeks was 70 per cent of the flow of Grand Central River below the forks.

During the season of 1907 gaging stations were maintained on all the streams which are summarized below, and their daily discharge is given elsewhere.

The following table should not be taken as indicating the water that can be used. This will, of course, be limited by the capacity of ditches that can be built economically. In the economical construction of a ditch the size will depend largely upon the duration of the low-water flow. This will probably limit the size in most cases to twice the minimum, except for short ditches.

Mean weekly water supply, in second-feet, available for use back of Nome, 1906-19

Date.	Available for use at elevation 220 to 280 feet.	Available for use at elevation 400 to 450 feet.				Total.
	Nome River low-level flow.	Nome River high-level flow.	Upper Grand Central, Thompson, and Gold Run.	Nugget, Copper, and Jett creeks.	Sinuk River, Windy and North Star creeks.	
1906.						
July 1-7	43	45	153	7	88	
July 8-14	155	144	[a] 343	26	173	
July 15-21	52	58	179	15	90	
July 22-28	43	49	156	12	79	
July 29-August 4	36	42	101	8	50	
August 5-11	39	45	108	8	49	
August 12-18	49	53	91	8	42	
August 19-25	81	84	138	10	62	
August 26-September 1	130	128	202	22	94	
September 2-8	68	73	101	14	51	
September 9-18	48	53	68	9	36	
September 19-30	120	118	250	20	125	
Mean	72	74	158	13	78	
Maximum	155	144	343	26	173	
Minimum	36	42	68	7	36	
1907.						
July 1-7	135	199	(b)	36	152	
July 8-14	102	152	292	27	172	
July 15-21	84	107	228	21	143	
July 22-28	60	77	183	15	105	
July 29-August 4	44	59	144	11	77	
August 5-11	36	49	107	8	50	
August 12-18	49	62	190	13	95	
August 19-25	47	61	245	15	86	
August 26-September 1	72	89	318	18	124	
September 2-8	51	63	142	14	72	
September 9-15	176	204	418	40	167	
September 16-23	60	76	115	24	62	
September 24-30	45	56	(b)	15	(b)	
Mean	74	98	216	20	109	
Maximum	176	204	418	40	172	
Minimum	36	49	107	8	50	

[a] Too small, no record of highest water.

[b] No record. No water could have been used from Grand Central River the first week in July account of snow; nor from either Grand Central or Sinuk rivers the last week in September, account of ice.

DITCH AND PIPE LINES.

In order to bring the water to the gold-producing ground between Capes Nome and Rodney at sufficient elevation to be used for hydraulicking and sluicing, nearly 300 miles of ditch and pipe line have been constructed and several extensive additional systems are now under construction or consideration. The first ditch in this section was built in 1901, by Leland, Davidson, and Bliss, from upper Glacier Creek to Snow Gulch. This ditch demonstrated the practicability of ditch systems in this country and was the beginning of the Miocene system.

Ditches are usually built so as to follow the contour approximately with grades limiting the velocity to about 2 feet per second, which is as high as the material in this section will stand without scour. The ditches are therefore for the most part on slopes, and are constructed by making a cut from 12 to 18 inches deep to grade at the lower bank. This bank is then built up by material from the excavation. The slopes of the banks are from 1:1 to 1½:1, depending on the material.

The work of constructing a ditch is usually divided into three classes—team work, pick and shovel work, and rock work. Teams may be used in handling dry soil that contains only medium-sized rock. This is the fastest method, and the compacting of the lower banks by the horses and scrapers makes it much tighter than when the dirt is thrown in loose. Pick and shovel are used in loose rock, in wet soil, and in frozen ground from which the top is removed as it thaws from the surface. Rock must be blasted, unless it is fissured limestone, which may be loosened with the crowbar, or decomposed schist, which yields to the pick. In building through solid rock, a shelf is blasted out about 1 foot below grade and wide enough to carry the ditch and the lower bank, which is built of rocks. The bottom and sides are lined with sod about 1 foot thick, and are puddled with clay. In rock slide the method is similar. A good example of this kind of construction was seen on the Grand Central branch of the Miocene system. The ditch was built through a pile of large bowlders, unmixed with any soil or gravel. A trench was made 1 foot deeper and 2 feet wider than the finished ditch. The sides of the trench were lined with a slope wall, laid 1 to 1, to a height of 4 or 5 feet. The outer slope of the lower bank was also rock wall, laid somewhat flatter. The ditch will be lined with sod and will be tight and permanent.

The use of sod is very common and economical, and saves much piping and fluming that would otherwise be necessary. The sod in a short time settles and knits together, and thus becomes a very serviceable bank. It will not cut or wear out, and the older it gets the better it becomes. In this way a ditch can be made over perpetually frozen ground, where otherwise it would be impossible. Much ditch has to be constructed over loose stones with little or no sediment between them. Such ditches must be lined with sod and all holes must be filled by tamping sod into them as far as possible. This being done, it will be found that the water traveling through the ditch will deposit sediment over the sod and that after a little while it will become tight.

Canvas is also used as a lining to make a ditch water-tight. Willows with the tops left out, so that they may grow, are utilized in embankments with success.

In construction over "glacier," which is the term used for frozen muck mixed with ground ice, the ditch is either built wholly on top of the sod covering or an excavation is made and lined with sod. Ditches over this material are expensive to maintain, owing to the thawing of the ice by the running water.

One of the most interesting pieces of construction over glacier is the flume on the Miocene ditch. This flume is 1,100 feet long, and has a width of 8 feet and a depth of 28 inches. It was constructed in 1901, and is now in practically perfect alignment, both horizontal and vertical, and no repairs have been necessary on it. In putting in the foundation, trenches were dug 3 or 4 feet deep in the frozen ground, which was practically all ice. The excavated material was covered to protect it from thawing. A sill was laid in the bottom of the trench and the uprights fastened to this sill. The excavated material was then replaced in the trenches and froze again into the original condition. Sod was carefully placed over the trench. The uprights were then sawed off to grade and the flume constructed on them.

Inverted siphons are built across deep ravines where their use will save expense and reduce loss by seepage. Most of these are riveted steel pipe. Joints are made by lapping the ends from 4 to 6 inches. Siphons must be weighted down and protected by rock to prevent injury by frost and snowslides. During 1906 two siphons were built on the Seward ditch, across Clara and Hobson creeks, continuous wood-stave pipes with steel bands being used.

On account of the rapid surface run-off during hard rains, it is necessary to have waste gates at short intervals. The most common waste gates consist either of a flume as deep as the bottom of the ditch, in which the height of the water is regulated by flashboards, or of a long weir, laid on the ground surface, which will spill the water when it reaches a certain level.

Ditch intakes consist of a dam or barrier across the stream, containing one or more waste gates, and head gates for regulating the flow into the ditch. In order to divert the entire flow of a stream, a bed-rock dam must be built to stop the ground flow through the gravelly beds. Such a dam is made by cutting a trench across the stream bed, extending down to an impervious stratum, and filling it with sod, which is carefully laid and tamped. The dam should be protected from erosion with large flat rocks or riprap.

Frozen ground, inadequate facilities for transportation, and the high cost of help[a] and supplies make ditching very expensive. To the first cost of a ditch should be added the cost of maintenance for the first three years, during which time extensive repairs are necessary. On many ditches these repairs cost as much as the first construction. At the end of three years ditches are, as a rule, in fairly permanent condition and the cost of maintenance is greatly reduced. Such information as could be obtained shows that the cost of a ditch carrying from 1,000 to 2,000 inches, including the first three years' maintenance, is from $5,000 to $10,000 per mile. Owing to dangers from washouts and landslides it is necessary to have the ditch constantly patrolled.

---

[a] Laborers receive $5 per day and board; blacksmiths, cooks, etc., $6.

Owing to the frozen condition of the ground it is not practicable to use ditches much before the 1st of July, as the surface does not become fully thawed until that time, and during the thawing period the ground becomes very soft and there is great danger of damage by washouts.

The following table gives a list of the principal ditches in this region. Some of the data given are only approximate, as it was necessary to obtain them by inquiry.

Ditches between Cape Nome and Cape Rodney, Seward Peninsula.

Name.	From—	To—	Length.	Date completed.	Bottom width	Fall per mile.	Capacity.	Elevation.	
								Head.	Outlet.
Miocene Ditch Co.:			*Miles.*		*Feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Feet.*
Main ditch...	Nome River...	Hobson Creek.	13	1903	8	4.5	40	572	500
	Hobson Creek.	The Ex........	14	1902	10	3.37	55	500	445
	The Ex........	Snow Gulch ...	4	1901	8	6.5	55	445	420
Feeding laterals.	Upper Glacier Creek.	The Ex........	2	1901	......	......	6	......	445
	Grouse Creek..	Flume.........	4	......	......	......	10	......	478
	Upper New Eldorado Creek.	Buster Creek..	10	1907	......	......	6	742	......
	David Creek...	Nome River above main intake.	1.8	1905	5	5.28	18	590	580
	Jett Creek.....	Nugget Divide.	3.5	1906	3.5	6	10	806	785
	Grand Central River.	.....do.........	8	([a])	8-10	5	80	850	785
Distributing laterals.	The Ex........	Grass Gulch...	4	......	6	3.17	16	445	432
	New Year Gulch.	Cooper Gulch..	4	1907	8	5.28	40	417	396
Tunnel.......	Kanoma Gulch, Glacier Creek	New Year Gulch, Anvil Creek.	[b] 1,800	1904	[c] 4x7	......	......	420	417
Wild Goose Mining and Trading Co.:									
Seward.......	Nome River below Dorothy Creek.	Anvil Creek...	38	1906	10	3.17	32	408	274
Pipe line.....	Crater Lake ...	Nugget Divide.	8	([a])	[d] 42	15	60	963	......
	Nugget Divide.	Anvil Mountain.	35	([a])	[d] 48	10	70	......	......
	Pumping plant.	.....do.........	7	......	[d] 18	......	6	......	......
	No. 3, below Little Creek.	Pumping plant.	3	1902	4	5.3	6	......	......
Pioneer Mining Co.:									
South bank..	No. 2, above Anvil Creek.	No. 1, below Anvil Creek.	0.75	1902	5	7	4-6	......	......
North bank..	No. 4, above Anvil Creek.	Moonlight Reservoir.	1.25	1903	6	......	10-12	......	......
	Nome River, above Clara Creek.	Little Creek...	38	1907	8	3.17	30	320	200

[a] Under construction.
[b] Feet.
[c] Cross section.
[d] Diameter in inches.

Ditches between Cape Nome and Cape Rodney, Seward Peninsula—Continued.

Name.	From—	To—	Length.	Date completed.	Bottom width.	Fall per mile.	Capacity.	Elevation.	
								Head.	Outlet.
			Miles.		*Feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Feet.*
United Ditch Co.:									
Sutton	Penny River	Beach	6	1905	20–15	3.12	40	120	90
Highline	do	Sunset Creek	10.5	(a)	7	4.22	......	420	......
Miscellaneous:									
Cedric	Josie Creek	Hungry Creek.	19	1905	4–8	4	25	870	790
Campion	Buffalo	Dorothy Creek.	4	1903	6	7.5	28	610	580
Peninsula Hydraulic Co.	New Eldorado Creek.	Osborn Creek	9	1907	14	......	50	......	......
Northland Mining Co.	Goldbottom Creek.	Balto Creek	12	(a)	......	......	20	390	......
Hot Air	Divining	Glacier Creek, opposite Snow Gulch.	6	1902	......	......	10	......	......
Price and Tremper.	Glacier Creek	Opposite Snow Gulch.	2.5	......	......	......	5	175	......
Golden Dawn.	Twin Mountain Creek.	Alpha Creek	10	(a)	......	......	20	500	......
Corson Mining Co.	Last Chance Creek.	Pioneer Gulch	4	1903	......	......	18	460	......
Plein	No. 7, Otter Creek.	Mouth	1	1904	......	......	3	......	......
Flambeau Hastings.	Head of Flambeau River.	Hastings Creek	29	1906	......	......	20	......	......
Capt. Peterson.	No. 3, below Anvil Creek	Little Creek	2.5	......	......	......	16	......	......
Cripple River Hydraulic Mining Co.	West bank Cripple River	Fox Gulch	11	(a)	8–10	4	50	......	......
Jourden-Cummings.	Buffalo Creek	Boer Creek	4	1906	4	6	10	1,000	......

[a] Under construction.

WATER-POWER POSSIBILITIES.

Owing to the great value of water in this region for use in working the auriferous gravels but little attention has been given to power development. In various portions of the peninsula there are, however, excellent power sites whose development is feasible from both an engineering and a financial standpoint. The scarcity of fuel makes steam power very expensive, and it is probable that much of the future mining, especially along the tundra back of Nome and along the larger streams, will be carried on by dredging or by some form of elevating in which power will play an important part. With this in view, the attention of capitalists should be directed to the consideration of power possibilities.

Work has been begun at Salmon Lake on the construction of a dam. (See p. 54.) The Three Friends Mining Company has started a ditch on Solomon River to develop power for its dredge.

Many streams in the Kigluaik Mountains, notably the glacier-fed torrents on their northern slope, are available for developments under a high head.

THE KOUGAROK REGION.

By Fred F. Henshaw.

INTRODUCTION.

In 1907 the investigation of streams begun the previous year in the Nome region was extended to the Kougarok region. Owing to the large area that had to be covered and the lack of railroad or other transportation facilities only a few regular stations were maintained, and on most of the streams only a few discharge measurements were made. The work was carried on by the writer, who was in this district from July 15 to September 18.

In the present report the name Kougarok region is used to include not only most of the Kougarok precinct, but parts of the adjoining Port Clarence and Goodhope precincts. The drainage basin of Kruzgamepa River, though included in the Kougarok precinct, has already been considered with the Nome region, with which it more naturally falls.

A summary of the records in this region is combined with one for the Nome region (see p. 95), in order to afford a comparison of conditions in the two districts.

DESCRIPTION OF AREA.

The Kougarok region lies northeast of the Kigluaik Mountains, in the central portion of Seward Peninsula. It is about 50 miles square, embracing the drainage basin of Kougarok River and parts of the adjoining basins of Noxapaga, Serpentine, and American rivers.

Most of this area is comprised in an upland which represents a former level of erosion. The flat-topped ridges of the hills lie at an elevation of 1,000 to 1,600 feet. Several mountain masses rise above the level of the plateau, notably Kougarok, Midnight, and Baldy mountains. Into this plateau the river channels are deeply cut. The streams flow in steep canyons, above which one or more levels of benches can usually be traced. The rivers drain southward into the Kuzitrin, which flows through the broad lowland basin separating this region from the Kigluaik Mountains.

The general slope of the rivers from source to mouth is more uniform than in the Nome region. The fall occurs mostly in riffles separated by pools of slack water. The stream beds are narrower and have shallower gravel deposits than most of the streams south of the mountains. (See Pl. VIII, *A*, p. 80.)

A large portion of the area, probably 40 to 60 per cent, is underlain with frozen muck and ground ice, which was observed in some places to have a thickness of 25 to 30 feet. This is covered with moss, and unless exposed by stripping never thaws deeper than a few inches.

CONDITIONS AFFECTING WATER SUPPLY.

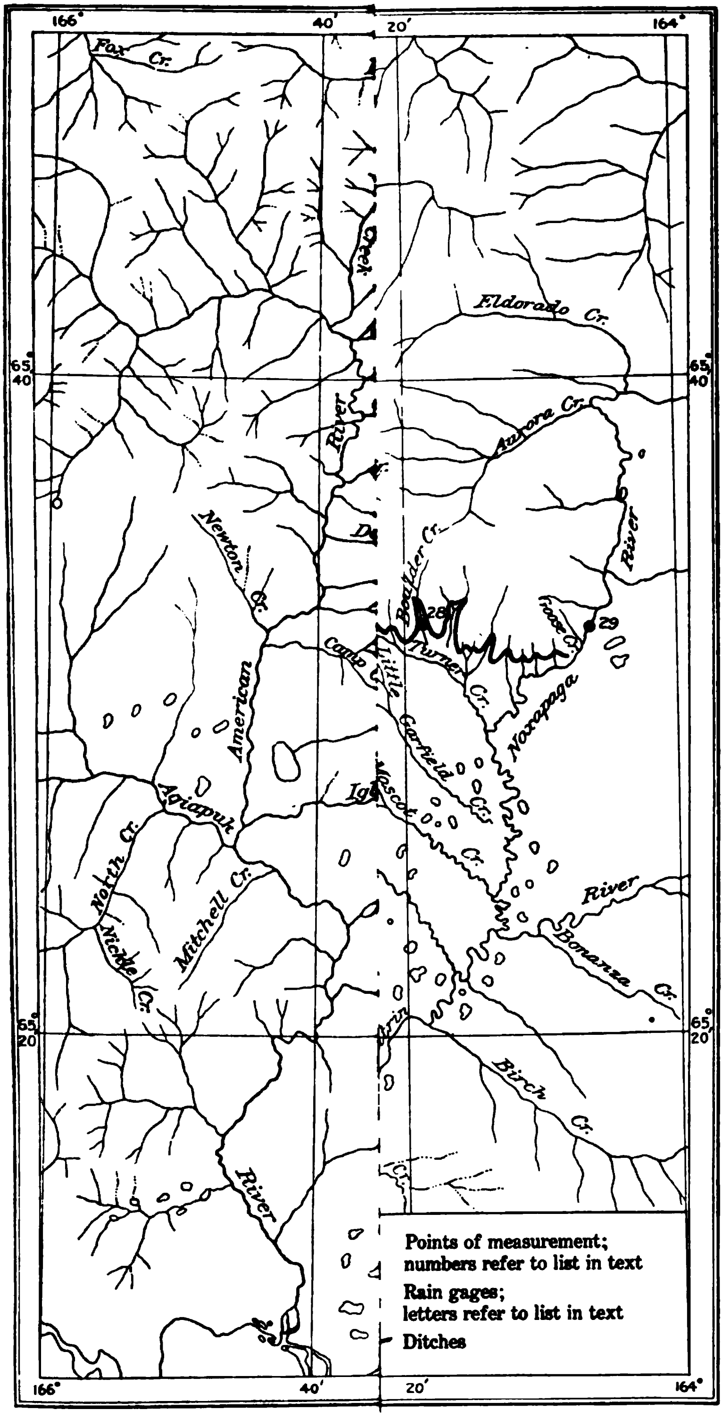
In general the water supply of the Kougarok region comes from the same sources as that of the Nome region, namely, summer rains, melting of snow, and melting of frozen ground.

The difference in rainfall between this area and that south of the mountains is striking. The totals of 2.51 and 2.79 inches for Shelton and Taylor, respectivly, are only about one-sixth of the total at Grand Central and only one-third to one-half of those of the other three rainfall stations. (See p. 137.) The Kougarok region is in a measure cut off from the comparatively abundant rainfall of the Nome region by the Kigluaik Mountains. This high and steep range causes most of the moisture from the southerly winds to be precipitated on its southern slope, leaving little to be carried into the region farther north. The northerly winds bring heavy clouds and fog banks from the Arctic Ocean, but they yield little rain.

In 1907 there was no rain in this region until the middle of July and very little until a month later, so that the run-off up to August 1 came mostly from melting snow. During the three weeks of extremely low water that followed the water must have been derived from the melting of the ground and the snow banks that still remained, partly from springs, and only to a slight degree from the rainfall.

The ground is all frozen muck, and is so protected by moss that it never thaws more than a few inches. There can be no regulation of flow by ground storage, therefore, and the rain finds its way into the streams immediately after it falls. This effect is more marked here than in the Nome region. Thus, on July 24, 1907, the flow of Taylor Creek rose from 10 to 186 second-feet in two or three hours, and four days later had fallen again to about 13 second-feet.

But little definite information can be obtained in regard to climatic conditions in former years in the Kougarok region. The last season was one of drought in that region, whereas the water supply south of the mountains was plentiful. The most reliable information that could be obtained was to the effect that the low-water periods of 1900


166°
40′
20′
164°
65° 40′
65° 20′
Fox Cr.
Creek
Eldorado Cr.
River
Aurora Cr.
River
Newton Cr.
Boulder Cr.
28
29
Goose Cr.
Camp Cr.
Little
Turner Cr.
Cr.
Noxapaga
American
Garfield Crs.
Agiapuk
Ig
Moscot
Cr.
North Cr.
Mitchell Cr.
Nickle Cr.
River
Bonanza Cr.
Birch Cr.
River
Cr.
Points of measurement;
numbers refer to list in text
Rain gages;
letters refer to list in text
Ditches

MA

and 1906 were fully as long and as severe as that of 1907. During the week of August 10 to 16, 1907, the flow at all the gaging stations remained nearly constant, and was probably as low as it would have become had the weather continued dry, as practically all the water must have come from springs and from the melting snow. Whenever there occurs a period of two weeks or more in midsummer without rain, the flow is likely to become as small as in 1907.

GAGING STATIONS.

The following is a list of the points in the Kougarok region at which gages were established or discharge measurements made in 1907. The numbers refer to Pl. VII.

Gaging stations in Kougarok region.

1. Kougarok River below Washington Creek, Washington Creek, and Irving ditch.
2. Kougarok River at Homestake intake and Homestake ditch.
3. Kougarok River above Taylor Creek.
4. Kougarok River above Coarse Gold Creek.
5. Homestake ditch at penstock.
6. Columbia Creek.
7. Macklin Creek.
8. Homestake Creek.
9. Taylor Creek at North Star intake.
10. Taylor Creek at Cascade intake.
11. Taylor Creek at mouth.
12. North Star ditch above siphon.
13. Cascade ditch.
14. Henry Creek at ditch intake.
15. Henry Creek at mouth.
16. Lincoln Creek at ditch level.
17. Lillian Creek.
18. California Creek.
19. Arctic Creek.
20. Arizona Creek.
21. Coarse Gold Creek.
22. North Fork at Northwestern intake.
23. North Fork above Eureka Creek.
24. Eureka Creek.
25. Windy Creek and ditch.
26. Coffee Creek and ditch.
27. Turner Creek at McKays intake.
28. Boulder Creek.
29. Noxapaga River above Goose Creek.
30. Schlitz Creek.
31. Reindeer Creek.
32. Bryan Creek.
33. Quartz Creek.
34. Bismark Creek.
35. Budd Creek spring.
36. Budd Creek below Windy Creek.

KOUGAROK RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Kougarok River drains a large area lying in the central portion of Seward Peninsula and empties into the Kuzitrin about 8 miles above Lanes Landing. It rises southeast of Kougarok Mountain and flows northward, then eastward, and after making a sharp bend to the right flows a little east of south to its mouth. The largest tributaries are Taylor Creek and North Fork from the east, and Henry, Coarse Gold, and Windy creeks from the west. Of less importance are Washington, Columbia, Macklin, Homestake, Goose, California, Arctic, Arizona, Louisa, Galvin, and Dan creeks, and Left Fork. Quartz Creek, which empties into the river below those named above. and its tributaries, Coffee, Dahl, Checkers, Carrie, and Independence creeks, have been the most important gold producers of the region. but have a very small run-off except at times of heavy rain.

KOUGAROK RIVER BELOW WASHINGTON CREEK.

The following measurements were made to determine the water supply available for the ditch of the Irving Mining Company, which is about 200 feet higher than the Homestake ditch: July 27, 4.5 second-feet; August 12, 2.2 second-feet; September 9, 122 second-feet.

KOUGAROK RIVER AT HOMESTAKE INTAKE AND HOMESTAKE DITCH.

These stations are located about 100 yards below the intake of Homestake ditch (see Pl. VIII, *A*), and the sum of their discharges gives the total flow of the river at this point. The gage was read by employees of the Kugarok Mining and Ditch Company.

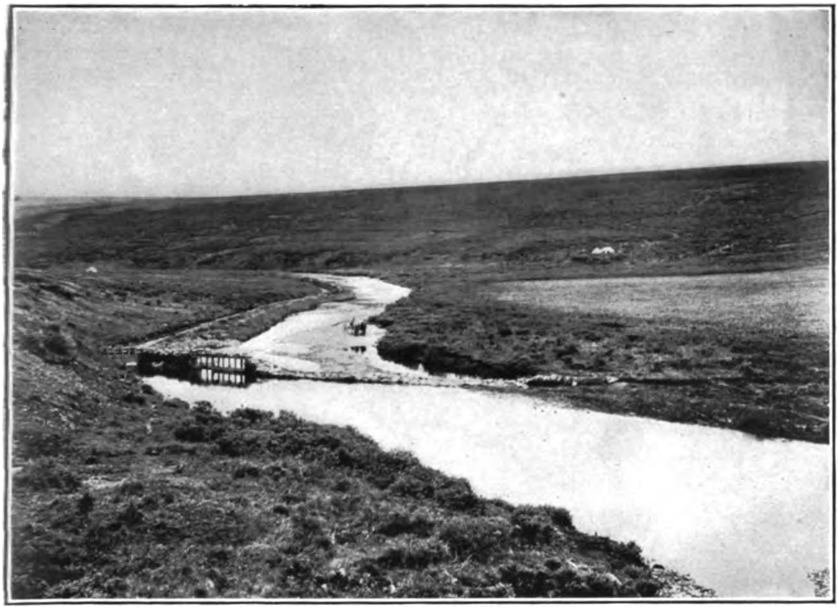
Discharge measurements of Kougarok River at Homestake intake and Homestake ditch, 1907.

KOUGAROK RIVER.

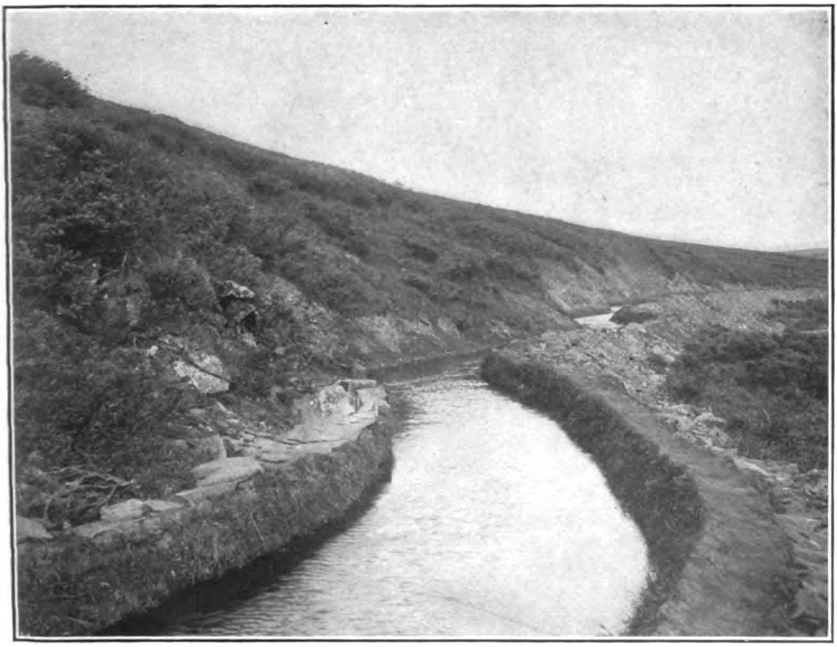
Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 15	1.24	18.0	August 22	1.64	82
Do	1.13	6.6	September 1	.89	.5
July 20	1.08	2.0	September 4	1.34	42
August 9	.92	3.1	September 10	2.47	303
August 12	.90	2.2	September 11	1.98	153
August 19	.92	3.3			

HOMESTAKE DITCH.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
July 15	0.51	11.6	August 19	0.28	7.4
Do	.45	10.2	Do	.27	7.3
Do	−.05	.4	August 22	.62	17.6
July 20	.36	8.1	Do	.75	23.0
July 29	.20	5.7	September 10	.44	12.0
August 12	−.04	1.5			



A. INTAKE OF HOMESTAKE DITCH ON KOUGAROK RIVER.



B. HOMESTAKE DITCH, SHOWING SOD WORK.

Daily gage height and discharge of Kougarok River at Homestake intake and Homestake ditch, 1907.

Day.	July.				August.				September.			
	River.		Ditch.		River.		Ditch.		River.		Ditch.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1						0.4	0.25	6.8	1.01	10.8	0.62	17.8
2						.4	.15	4.8	1.15	22	.66	19.4
3						.4	.18	5.3	1.12	20	.68	20.2
4						.4	.32	8.5	1.35	42	.64	18.6
5						.4	.28	7.5	1.57	71	.58	16.3
6						.4	.20	5.7	1.44	53	.64	18.6
7						.4	.16	4.9	1.28	35	.64	18.6
8						.4	.10	3.8	1.16	23	.65	19.0
9					0.92	3.2	.06	3.2	1.78	110	.69	20.6
10					.90	2.2	−.02	2.0	2.56	336	.55	15.2
11					.90	2.2	−.03	1.8	1.86	124	.62	17.8
12					.90	2.2	−.04	1.7	1.54	67	.65	19.0
13					.89	1.7	−.06	1.5	1.33	40	.66	19.4
14					.90	2.2	−.06	1.5	1.17	24	.66	19.4
15	1.24	18		0	.91	2.7	−.08	1.2	1.74	99	.66	19.4
16		3.0		13.0	.91	2.7	−.08	1.2	1.50	61	.68	20.2
17		3.0		12.0	.91	2.7	+.04	2.8	1.22	29	.69	20.6
18		3.0		10.0	.92	3.2	.12	4.2	1.11	18.9	.70	21.0
19		3.0		9.0	.92	3.2	.28	7.5	1.04	13.2	.62	17.8
20	1.08	2.9	0.36	8.0	.91	2.7	.18	5.3	1.10	18.0	.30	8.0
21	1.05	2.0	.40	9.0	1.40	48	.60	17.0				
22	1.04	1.6	.31	6.7	1.71	93	.61	17.4				
23	1.00	.4	.34	7.4	1.58	72	.61	17.4				
24	1.20	14.0	.62	15.4	1.17	24	.63	18.2				
25	1.03	1.3	.55	15.2	1.54	67	.58	16.3				
26	1.00	.4	.49	13.2	1.28	35	.59	16.6				
27	.88	.4	.42	11.1	1.22	29	.66	19.4				
28	.89	4	.26	7.1	1.09	17	.62	17.8				
29		.4	.22	6.2	.96	5.8	.61	17.4				
30		.4	.21	5.9	.95	5.0	.69	20.6				
31		.4		6.4	.89	.5	.57	16.0				
Mean	......	3.2	......	9.2	......	13.9	......	8.9	......	60.8	......	18.3

NOTE.—Discharges for July 16 to 19 are estimated. All water was carried in the ditch from July 26 to August 8, inclusive, except the seepage through the diversion dam, which was estimated. During this time about 2 second-feet was turned out of the first waste gate to furnish a sluice head for operators who were working in the river bed below.

Monthly discharge of Kougarok River at Homestake intake, 1907.

[Drainage area, 44 square miles.]

Month.	Discharge in second feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Sec.-ft per sq. mile.	Depth in inches.
July 15-31	29	6.3	12.4	0.28	0.18
August	110	3.2	22.8	.52	.60
September 1-20	351	26	79.1	1.80	1.34
68 days	351	3.2	36.8	.84	2.12

NOTE.—These values include the discharge of both the river and Homestake ditch, as given in the previous table.

KOUGAROK RIVER ABOVE TAYLOR CREEK.

The following measurements were made just above the mouth of Taylor Creek, to compare the flow of the two forks at their junction, and to determine the discharge available for a ditch at this level: July 26, 18.5 second-feet; July 29, 8 second-feet; August 10, 5.1 second-feet.

KOUGAROK RIVER ABOVE COARSE GOLD CREEK.

Between the mouths of Taylor Creek and North Fork, Kougarok River has a meandering course, with well-marked benches along most of the distance. At the mouth of Coarse Gold Creek it makes a bend which brings two points more than 2 miles apart by river within 560 feet of each other in a straight line. A tunnel through this neck would drain the gravels in this stretch of river bed and make them accessible for working, and would also render available a considerable water power. The difference in level of the water surface at the two ends of the tunnel is about 17 feet. An outcrop of rock which crosses the river just below the proposed tunnel intake would make a fairly good dam site. A gaging station was established at this point July 15, 1907. The gage was located just above the rock outcrop mentioned above, where the channel is permanent, and was read by William Ellis. The bench mark is a cross on the highest point of a rock near the left bank, about 200 feet above the tunnel entrance; elevation, 2.18 feet above the datum of the 1907 gage.

The discharge at this station also gives the water supply that would be available for a low-line ditch to Dahl Creek. Such a ditch is proposed. It will have its intake on Kougarok River below Dreamy Gulch and on Henry Creek near the mouth, and will extend to Dahl and Coffee creeks, a distance of over 30 miles. Only a small percentage of the water enters the river between these proposed intakes and the gaging station.

Discharge measurements of Kougarok River above Coarse Gold Creek, 1907.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 14	1.11	89	August 8	0.44	19
July 21	.86	51	August 14	.40	17
July 23	.74	36	August 23	2.22	410
July 30	.64	33	August 26	1.95	333

Daily gage height and discharge of Kougarok River above Coarse Gold Creek, 1907.

[Drainage area, 250 square miles.]

Day.	July.		August.		September.		Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.70	35		210	19	0.90	54	1.12	92		160
2			.63	31		230	20	.84	47	1.08	84		130
3			.60	29		205	21	.82	45	1.68	229		
4			.63	31		280	22	.82	45	2.25	490		
5			.60	29		500	23	.75	39	2.22	472		
6			.57	27	2.15	430	24	1.14	96	2.19	454		
7			.50	23	2.10	400	25	1.58	200	2.22	472		
8			.46	21	1.80	270	26	1.20	109	1.99	341		
9			.38	16		600	27	1.06	81		280		
10			.38	16	3.50	1,240	28	.83	46		240		
11			.38	16		550	29	.70	35		210		
12			.37	16		350	30	.66	33		360		
13			.39	17	1.80	270	31	.72	37		190		
14	1.09	86	.40	17	2.23	478	Mean		67.2		141		388
15	1.03	75	.40	17		600	Run-off per square mile		.27		.56		1.55
16	.98	67	.43	19		380							
17	.90	54	.50	23		270	Run-off, depth in inches		.18		.65		1.15
18	.94	60	1.03	75		200							

NOTE.—Discharges for days when gage was not read were estimated with the aid of a hydrograph.

IRVING DITCH.

The Irving ditch was built in 1906, and has its intake on Kougarok River at the mouth of Washington Creek. It extends for 4½ miles along the north bank of the river to a point opposite the mouth of Columbia Creek, where a head of 160 feet is obtained.

The following measurements were made of the discharge of the ditch: August 12, 1.8 second-feet; September 9, 12.4 second-feet.

HOMESTAKE DITCH.

The Homestake ditch of the Kugarok Mining and Ditch Company was begun in 1905 and completed in 1907. It diverts the water from the upper Kougarok, near Mascot Gulch, and extends along the left bank of the river to a point opposite the mouth of Homestake Creek, having a total length of 7½ miles. The water is carried across Macklin Creek in a siphon 843 feet long, of 36 and 34 inch pipe.

Above Macklin Creek the ditch is built into the rocky bluffs of close-grained schists and slates for about 1 mile. Below the siphon some ground ice was encountered, and also a large amount of loose rock mixed with ice and frozen muck, which gave much trouble. Nearly half of the length of the ditch had to be lined with sod, some parts requiring both sides and bottom of this material. (See Pl. VIII, *B*.) In 1907 a lateral ditch was built to Macklin Creek. It is 6,300 feet long and 4 feet wide on the bottom.

The water was used during the latter part of 1906 in the bed of the river just above Taylor Creek. A waste ditch was formed by a retaining wall built on one side of the channel, but at times this was overtopped and the workings flooded. The discharge at such times was estimated at 600 to 800 second-feet.

During the season of 1907 the water was used on the John L. bench claim, on the right bank of the river below Homestake Creek. A head of about 150 feet is available on this claim.

Two stations were maintained on the ditch, at the intake and just above the penstock. The discharge at the intake is given on page 81.

The station above the penstock was maintained during the high-water period of 1907, to determine the amount of water used at the mine. The gage was read by employees of the Kugarok Mining and Ditch Company.

Discharge measurements of Homestake ditch above penstock, 1907.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
August 21	1.19	9.1	August 26	1.60	18.0
Do	1.49	15.6	September 11	1.74	21.0
August 22	1.47	15.0			

Daily gage height and discharge of Homestake ditch above penstock, 1907.

Day.	August.		September.		Day.	August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.76	21.5	18			1.76	21.5
2			1.70	20.2	19			1.68	17.8
3			1.62	18.4	20			1.15	8.4
4			1.75	21.3	21	1.34	12.3		
5			1.54	16.7	22	1.48	15.4		
6			1.70	20.2	23	1.54	16.7		
7			1.70	20.2	24	1.54	16.7		
8			1.70	20.2	25	1.60	18.0		
9			1.72	20.6	26	1.60	18.0		
10			1.52	16.2	27	1.56	17.1		
11			1.74	21.1	28	1.58	17.6		
12			1.75	21.3	29	1.58	17.6		
13			1.76	21.5	30	1.68	19.8		
14			1.76	21.5	31	1.70	20.2		
15			1.76	21.5					
16			1.74	21.1	Mean		17.2		19.6
17			1.76	21.5					

TAYLOR CREEK AT NORTH STAR INTAKE.

Taylor Creek is the longest tributary of Kougarok River and is larger than the main stream at their junction. It rises near the headwaters of Noxapaga and Goodhope rivers and flows in a southwesterly direction. Its principal tributaries are Midnight, Solomon, Jim, Brown, Rock, and Arizona creeks. Two ditches have been built on Taylor Creek—the North Star, with its intake about 3 miles above Solomon Creek, and the Cascade, which takes out water about 5 miles farther downstream.

The following measurements were made at North Star intake to determine the water supply available for the ditch: July 17, 12 second-feet; July 24, 174 second-feet; August 10, 3.8 second-feet; September 13, 94 second-feet. They indicate a discharge of 75 to 90 per cent of that at the Cascade intake; the drainage area is 58 square miles, or 78 per cent of that at the lower point.

TAYLOR CREEK AT CASCADE INTAKE.

This station was established to determine the total water supply of the two ditches on Taylor Creek. It is located about 100 yards above the diversion dam of the ditch. During August and September a part of the discharge of the creek was diverted past the station in the North Star ditch; the amount of this diversion is given on page 87. The gage was read by employees of the Cascade Mining and Ditch Company.

Discharge measurements of Taylor Creek at Cascade intake, 1907.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 17	0.67	16	August 10	0.49	4.6
July 24	1.65	186	August 21	1.95	268
July 26	.93	43	August 24	1.30	91

Daily gage height and discharge of Taylor Creek at Cascade intake, 1907.

Day.	July.		August.		September.		Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet*	*Sec.-ft.*
1				7	1.12	67	18		20	0.84	32	1.00	50
2				7	1.24	87	19		15	1.15	72		45
3				7	1.15	72	20		13	.95	44		35
4				6	1.25	89	21		13	1.60	164		
5				6	1.55	152	22		12	1.48	136		
6				6	1.36	110	23		10	1.38	114		
7				5	1.25	89	24	1.65	186	1.25	89		
8				5	1.00	50	25		80	1.65	178		
9				4.6	1.24	87	26	.93	43		147		
10			0.49	4.6	2.40	430	27		25	1.39	116		
11				4	1.80	220	28		13		98		
12				4	1.45	129	29		8	1.20	80		
13			.31	2.5	1.30	98	30		8	1.65	178		
14			.42	3.9	1.15	72	31		8	1.20	80		
15		20	.47	4.6	1.60	164							
16		18	.50	5.0	1.30	98	Mean		29.9		52.2		111
17	0.67	16	.57	9.2	1.15	72							

NOTE.—Discharges for days on which gage was not read were obtained by the aid of a hydrograph.

Monthly discharge of Taylor Creek at Cascade intake, 1907.

[Drainage area, 74 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Sec.-ft. per sq. mile.	Depth in inches.
July 15-31	186	8	29.9	0.40	0.25
August	186	3.9	54.2	.73	.84
September 1-20	441	35	119	1.61	1.20
68 days	441	3.9	67.1	.91	2.29

NOTE.—These values include the discharge of both the creek and North Star ditch; for daily discharge of the ditch see page 87.

TAYLOR CREEK AT MOUTH.

The following measurements of Taylor Creek were made near the mouth, to compare its discharge with that of Kougarok River above the mouth of Taylor Creek and to determine the discharge available for a ditch at this level: July 17, 18 second-feet; July 26, 46 second-feet; July 29, 9.6 second-feet; August 10, 7.2 second-feet.

NORTH STAR DITCH ABOVE SIPHON.

The North Star ditch of the Taylor Creek Ditch Company was begun in 1905 and completed in 1907. It diverts water from Taylor Creek about 12 miles above its mouth and about 3 miles above the mouth of Solomon Creek. The ditch lies on the left bank for the first mile, then crosses the creek in a flume and continues on the right bank to a point 7 miles below the intake. Here it crosses Taylor Creek in a siphon 2,600 feet long, composed of 40-inch steel pipe, riveted throughout, there being no slip joints. The pipe is carried across the creek on a suspension bridge about 100 feet long. The difference in elevation between the ends of the siphon is 19 feet, and the depression at the bottom 150 feet. Below the siphon the ditch receives the flow of Rock Creek and continues to Arctic Creek, having a total length of 15.2 miles.

Water was turned into the ditch at the intake about August 5, but was not run through the siphon until about the 20th. The water was used on the Thorson bench, on the left bank of Kougarok River, and for stripping on Dreamy Gulch, a small tributary from the east.

The station above the siphon was established to determine the amount of water diverted past the gage at the Cascade intake. The quantity used at the mines includes in addition the discharge of Rock Creek. The gage was read by employees of the Taylor Creek Ditch Company.

Discharge measurements of North Star ditch above siphon, 1907.

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
August 10		[a]2.9
August 21	1.05	5.0
August 24	.50	0.0
September 5	1.14	7.0
September 13	1.24	9.7
Do		[a]8.0

[a] Measured at intake.

Daily gage height and discharge of North Star ditch above siphon, 1907.

Day.	August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.21	8.8
2			1.16	7.5
3			1.11	6.2
4			1.16	7.5
5			1.18	8.0
6			1.17	7.8
7			1.18	8.0
8			1.14	7.0
9			1.14	7.0
10			1.28	11.3
11			1.30	12.0
12			1.22	9.2
13		[a]1.5	1.25	10.2
14			1.24	9.9
15			1.30	12.0
16			1.28	11.3
17			1.22	9.2
18			1.22	9.2
19				
20				
21				
22	1.04	5.0		
23	1.09	5.8		
24				
25	1.18	8.0		
26	1.14	7.0		
27	1.05	5.2		
28	1.15	7.2		
29	1.18	8.0		
30	1.14	7.0		
31	1.16	7.5		
Mean		[b]6.2		9.0

[a] Estimated.

[b] Ten days.

CASCADE DITCH.

The Cascade ditch was built in 1906. It diverts water from Taylor Creek about 7 miles above its mouth and 110 feet lower than the North Star ditch. For the first quarter of a mile the ditch lies on the left bank of the creek; it then crosses to the right bank in a flume about 60 feet long, and extends within a half a mile of the mouth of Taylor Creek, having a total length of 6¼ miles. The flow of the ditch was very irregular during 1907, on account of breaks, repairs, and interruption of work at the mine. The water was used to run a hydraulic elevator in the bed of Taylor Creek. The water supply of the ditch was insufficient for this purpose during the first two weeks of August, and the pit was flooded on account of insufficient waste-way capacity most of the time after August 20.

The following measurements were made of the discharge of the ditch:

Discharge measurements of Cascade ditch, 1907.

Date.	Place.	Discharge.
		Sec.-ft.
August 10	Flume near intake	4.4
August 18	Near penstock	5.8
August 21	do	4.5
September 5	do	7.1

HENRY CREEK.

Henry Creek, which enters Kougarok River about 2 miles below the mouth of Taylor Creek, is the largest tributary from the west, and in dry weather furnishes the steadiest high-level water supply in the Kougarok drainage area. Its headwaters lie south of the upper Kougarok River and adjoin those of Budd Creek on the west. Lincoln Creek, which rises between Henry and Coarse Gold creeks, is the most important tributary. Lillian Creek enters from the north, about 4 miles from the mouth.

The Henry Creek ditch, which was built by the T. T. Lane Company in 1905 and 1906, extends from Henry Creek about 2 miles above the mouth of Lincoln Creek to a point near the mouth of Homestake Creek, and has a total length of 10¼ miles. An additional 3¼ miles would divert Lincoln Creek. No water was running in the ditch in 1907. It is now the property of the Taylor Creek Ditch Company.

Measurements were made at the ditch intakes and also at the mouth. The total flow at ditch level on the dates when it was measured was about 70 per cent of that at the mouth, and has been estimated as the same proportion for days when measurements were made only at the mouth.

Discharge measurements of Henry and Lincoln creeks, 1907.

Date.	Henry Creek at mouth.	At ditch level.		
		Henry Creek.	Lincoln Creek.	Total.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft*
July 16	....	10.0	8.2	18.2
July 25	22.0	7.4	8.0	15.4
July 30	9.6	....	....	6.8
August 9	8.2	....	....	5.7
August 13	6.8	2.7	2.3	5.0
August 20	12.0	5.0	3.3	8.3
August 23	60	....	....	42
August 26	34	....	....	24
August 29	27	....	....	19
September 6	55	....	....	38
September 12	99	41	42	83

The following measurements of Lillian Creek show the amount of water it would contribute to the Henry Creek ditch: July 16, 1.0 second-feet; August 20, 0.6 second-feet; September 12, 6 second-feet.

COARSE GOLD CREEK.

Coarse Gold Creek is one of the larger tributaries of Kougarok River. It has a total length of about 16 miles, and flows in a northeasterly direction, entering the river about 25 miles above the mouth. The creek is relatively flat in its upper portion, and has a fall of 40 to 80 feet per mile in the lower 6 miles.

The Coarse Gold ditch, constructed in 1907, has its intake about 5 miles above the mouth, and is built along the south slope of the valley, picking up the flow of Jones Gulch and Nugget Gulch. It extends about 5 miles to Two-bit Gulch, a small tributary of Kougarok River, where a head of nearly 300 feet is obtained. Measurements were made near the mouth of the creek. They show the water supply available for the ditch, as practically the whole flow is diverted.

Discharge measurements of Coarse Gold Creek near mouth, 1907.

Date.	Discharge.	Date.	Discharge.
	Sec.-ft.		*Sec.-ft.*
July 21	7.8	August 26	29
July 30	3.5	August 28	30
August 8	3.4	September 6	29
August 12	3.0	September 8	22
August 23	44	September 15	156

NORTH FORK.

North Fork is formed by the junction of French and Alder creeks and enters Kougarok River from the east, about a mile below the mouth of Coarse Gold Creek. Its principal tributaries are Harris, Baldy, Monument, Queen, Magnet, and Eureka creeks. Harris Creek is dry during low water for the lower 4 miles, the water flowing underground through the limestone which forms its bed. The flow of North Fork also is underground for over a mile, and appears again as a spring about a mile above Harris Creek.

In 1906 the Northwestern Development Company began a ditch which has its intake just below the junction of French and Alder creeks, extends along the north bank about 3 miles, and then crosses in a siphon to the south bank. Six miles of ditch are completed.

A lower ditch is proposed which will take its water above Eureka Creek and will extend to Dahl Creek. Measurements were made to show the water available for both ditches.

Discharge measurements of North Fork, 1907.

Date.	At Northwestern intake (drainage area, 20 square miles).	Above Eureka Creek (drainage area, 66 square miles).
	Sec.-ft.	*Sec.-ft.*
July 22	2.5	13.0
August 15	.7	9.6
August 27	31	103
September 7	17	70
September 15	[a]36	122

[a] Estimated.

MISCELLANEOUS MEASUREMENTS.

Measurements of a number of the smaller streams and ditches in the Kougarok drainage are given in the following table. Their location is indicated on the map (Pl. VII, p. 78). Macklin Creek is tapped about 1 mile from the mouth by a branch of the Homestake ditch. The Okdurok ditch diverts the flow of Homestake Creek.

The Arizona Creek ditch is 2 miles long and is built to the benches of the Kougarok, having an elevation of 185 feet above the river. The Windy Creek ditch is 4 miles long and gives a head of 150 feet above the creek at Anderson Gulch, where the water is used for ground sluicing. The McMonagle, Dolan & McFadden, and Blocker & Sayle ditches divert water from Kougarok River between the Homestake intake and Macklin Creek, and are used to furnish a sluice head for shoveling into boxes.

Miscellaneous measurements in Kougarok River drainage basin, 1907.

CREEKS.

Date.	Stream and locality.	Discharge.
		Sec.-feet.
July 21	Arctic, near mouth	0.6
August 26	do	1.5
September 6	do	3.0
August 29	Arizona, including ditch	5.1
September 8	do	6.2
August 29	California, near mouth	1.1
July 12	Coffee, near Wonder Gulch	.5
July 27	Columbia, near mouth	1.5
September 9	do	19
September 7	Eureka, near mouth	5.8
July 22	Harris, claim 15	1.0
August 22	Homestake, including ditch	4.0
September 6	do	5.7
August 19	Macklin, including ditch	5.5
August 22	do	19
September 11	do	20
August 12	Washington, near mouth	17
September 9	do	40
July 13	Windy, including ditch	9.0
July 31	do	4.8
August 8	do	3.0

DITCHES.

Date.	Stream and locality.	Discharge.
August 29	Arizona Creek ditch	1.8
September 8	do	1.9
August 19	Blocker & Sayle ditch	3.0
September 11	do	4.1
August 19	Dolan & McFadden ditch	2.5
Do	Macklin branch	4.0
Do	McMonagle ditch	3.0
August 22	Okdurok ditch	3.0
September 6	do	2.3
July 31	Windy Creek ditch	1.8
August 8	do	1.0

TOTAL WATER SUPPLY IN 1907.

The amount of water that would have been available in 1907 for the use of the principal ditches of the Kougarok drainage basin.

built and proposed, is summarized by weekly periods in the accompanying table. The following points should be noted:

The flow available "for Dahl Creek at elevation 300 to 350 feet" is the quantity that could have been diverted by proposed low-line ditches, one taking water from Kougarok River near Dreamy Gulch and from Henry Creek near the mouth, the other from North Fork above Eureka Creek. These ditches could be combined into one below the mouth of North Fork. The water in the North Star and Henry Creek ditches could be carried past the intakes and used below them, so that the flow available for the low-line ditch as given in the table would be reduced by the amount so diverted. Practically none of the discharge of Coarse Gold Creek would be available for this ditch, as it would be used in the high-level ditch.

The flow available for "upper Kougarok at elevation 600 to 700 feet" is the sum of the discharges of the five principal forks of the river at the ditch intakes. At least 75 per cent of the discharge of Taylor Creek is available for the North Star ditch and the remainder for the Cascade ditch. The values for Henry and Coarse Gold creeks and North Fork were estimated with the aid of hydrographs and are only approximate.

Several other streams would furnish some water at high and low level, notably Homestake and Rock creeks. At low water this would be less than 1 second-foot for any single stream and may be disregarded; at high water it would not be needed.

Mean weekly water supply, in second-feet, of Kougarok River drainage basin, 1907.

Date.	For Dahl Creek at elevation 300 to 350 feet.			For upper Kougarok at elevation 600 to 700 feet.					
	Kougarok River.	North Fork.	Total.	Kougarok River.	Taylor Creek.	Henry Creek.	Coarse Gold Creek.	North Fork.	Total.
July 15-21	57	22	79	14	16	19	12	5.2	66
July 22-28	88	22	110	13	53	14	9.6	3.0	93
July 29-August 4	33	12	45	6.7	7.3	7.3	3.8	1.2	26
August 5-11	21	10	31	5.4	5.0	6.3	3.3	1.0	21
August 12-18	26	13	39	4.5	9.0	5.4	3.9	1.0	24
August 19-25	328	73	401	60	117	28	29	30	264
August 26-September 1	262	83	345	33	117	21	26	27	224
September 2-8	331	76	407	57	100	33	27	21	238
September 9-15	584	117	701	133	181	94	100	44	552
September 16-20	228	45	273	46	68	33	39	17	203
Mean	196	47	243	37.3	67.3	26.1	25.4	15.0	171
Maximum	584	117	701	133	181	94	100	44	552
Minimum	21	10	31	4.5	5.0	5.4	3.3	1.0	21

NOXAPAGA RIVER DRAINAGE BASIN.

Noxapaga River is the largest tributary of the Kuzitrin, and enters that stream from the north about 15 miles above the mouth of the Kougarok. The northwestern portion of its basin resembles that of Kougarok River, which it adjoins. An extensive lava flow covers the eastern portion, and the southern or lower end lies in the lowland area known as the Kuzitrin Flats.

Above the mouth of Goose Creek the river has been crossed by a recent lava flow, forming rapids in which there is a descent of 96 feet in 2.3 miles. Above the rapids the river has hardly any fall for several miles.

During 1907 a ditch was built by the McKay Hydraulic Mining Company from Turner Creek, a tributary to the Noxapaga from the northwest, to benches on the river above Goose Creek. It has a total length of 16 miles, and diverts water from Turner, Boulder, Miller, Winona, and several smaller creeks.

Measurements were made in this drainage basin at extreme low water and in no wise represent the average flow. The seasonal variation of the smaller streams was probably as great as in the Kougarok River basin, and the high-water discharge of the Noxapaga can probably be safely estimated as the same per square mile as that of the Kougarok.

Discharge measurements in Noxapaga River drainage basin, 1907.

Date.	Stream and locality.	Drainage area	Discharge.
		Sq. miles.	*Sec.-feet.*
August 15	Turner Creek at McKay intake	13	0.7
Do	Boulder Creek at claim 5		.8
August 16	Noxapaga River above Goose Creek	340	62

SERPENTINE RIVER DRAINAGE BASIN.

Serpentine River drains a large area lying north of the Kougarok. Measurements were made of only a few streams in the headwaters.

SCHLITZ AND REINDEER CREEKS.

These creeks rise on the slope of Midnight Mountain, and flow northwestward into Serpentine River. A ditch has been started by the Kugarok Mining and Ditch Company which will be about 8 miles long and will divert the flow of these creeks over a low divide into Macklin Creek, where it will be picked up by a branch of the Homestake ditch. Measurements were made near the proposed diversions, as follows: Schlitz Creek, August 11, 0.7 second-feet; September 4, 13 second-feet. Reindeer Creek, August 11, 1.9 second-feet; September 3, 13 second-feet.

BRYAN AND DICK CREEKS.

Bryan Creek rises to the east of Kougarok Mountain and flows northeastward into Serpentine River. Dick Creek is its principal tributary and has shown the best values of all the streams in this drainage basin. A ditch built by the Pittsburg-Dick Creek Mining Company in 1906 and 1907 diverts the water of Bryan Creek and extends along the left or north bank of the creek for 6½ miles to the mouth of Dick Creek, where a head of about 170 feet is available. The following measurements were made of Bryan Creek near the intake: July 19, 4.2 second-feet; July 27, 6.0 second-feet; July 28, 6.5 second-feet; September 2, 15.5 second-feet.

QUARTZ AND BISMARCK CREEKS.

Quartz Creek is the name applied to the headwaters of South Fork of Serpentine River. It rises west of Kougarok Mountain and flows in a northerly direction. Bismarck Creek is a small tributary of Quartz Creek. In 1907 the Pittsburg-Dick Creek Mining Company began a ditch which will take water from these creeks and carry it over the divide to a small tributary of Bryan Creek, where it will be picked up by the Bryan Creek ditch. The Quartz Creek ditch is about 350 feet higher than the Bryan Creek ditch and is about 8 miles long. Plans are made to extend it to upper Dick Creek, giving it a total length of 22 miles. Measurements were made about 200 feet lower than the intakes, and not over 75 per cent of the discharge at these points would be available for the ditch.

The gage on Quartz Creek was read during the low water of August by S. G. Revelas.

The following measurements were made of Bismarck Creek: July 19, 1.7 second-feet; July 28, 2.0 second feet.

Gage heights and discharges of Quartz Creek, 1907.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
MEASUREMENTS.	*Feet.*	*Sec.-feet.*	GAGE READINGS—cont'd.	*Feet.*	*Sec.-feet.*
July 19	....	8.2	August 5	0.60	9.0
July 28	0.60	9.0	August 7	.61	9.6
September 2	.80	25.0	August 9	.62	10.2
			August 11	.60	9.0
GAGE READINGS.			August 13	.62	10.2
			August 15	.62	10.2
August 1	.61	9.6	August 17	.64	11.4
August 3	.60	9.0	August 19	.64	11.4

AMERICAN RIVER DRAINAGE BASIN.

American River, the north fork of the Agiapuk, drains a large area west of the Kougarok basin. Measurements were made only on Budd Creek, the tributary on which the most extensive development work has been done.

Budd Creek rises northwest of Kougarok Mountain and flows southeastward to the mouth of Eldorado Creek, thence southwestward to American River above the forks. The waters of Budd and

Eldorado creeks sink into the limestone which forms their beds, and after flowing from 2 to 4 miles underground appear as springs. Windy Creek is a large tributary from the south, on which some mining has been done.

In 1907 a ditch was built on the north bank of Budd Creek by the Ottumwa Gold Mining Company. It takes its water just below the spring and extends to a point below the mouth of Windy Creek, a distance of 8 miles. A head of about 160 feet is obtained. A second ditch was built by the same company on Million and Ohio creeks, tributaries of Windy Creek.

The following measurements were made August 31, when the water was at about as low a stage as it reached during the season, the rains beginning later here than in the Kougarok basin: Budd Creek Spring, drainage area 58 square miles; discharge, 25 second-feet. Budd Creek below Windy Creek, drainage area, 108 square miles; discharge, 39 second-feet.

HYDRAULIC DEVELOPMENT.

The first discovery of gold on any tributary of Kougarok River was made on Harris Creek in 1900. The river and creek claims were nearly all staked during the following summer, and values were found at many points. The district has continued as a producer since that time, but the total output of precious metal has been small compared with that of other districts in Seward Peninsula. In the lower part of the Kougarok region Dahl Creek has been the largest producer. Work on this stream is greatly handicapped by the scarcity of water. Dahl Creek has a small area and lies in a region of small run-off, so that it is only during the melting of the snow in the spring and for a few days after a heavy rain that enough water for sluicing can be obtained from the creek.

During 1903 and 1904 the first ditch in the region was built by the T. T. Lane Company. It extends from Coffee to Dahl Creek, diverting Carrie and Independence creeks along its course. In 1904 capital began to turn its attention to the upper Kougarok. Three large ditches were begun late that year or early in 1905—the Homestake, North Star, and Henry Creek ditches. In 1906, the Cascade, Irving, and North Fork ditches were built, and work was continued on the other three. In 1907 only one ditch, that on Coarse Gold Creek, was built in the Kougarok basin. Several developments were carried out on streams in adjacent drainage areas, including the McKay ditch from Turner Creek to Noxapaga River, the Bryan and Quartz creek ditches, and the Ottumwa ditch on Budd Creek. Most of these ditches have been described in the foregoing pages. The following tables summarize their principal features. The capacities are approximate in most cases.

Ditches in Kougarok region, Seward Peninsula.

Name.	Diverts from—	Extends to—	Date completed.	Length.	Bottom width.	Fall per mile.	Capacity.	Pressure obtained.
Kugarok Mining and Ditch Co.:				*Miles.*	*Feet.*	*Feet.*	*Sec.-ft.*	*Feet.*
Homestake	Kougarok River	Homestake Creek.	1907	7.5	8	3.17–4.22	25	160
Macklin Branch	Macklin Creek	Main ditch	1907	1.2	4	4.22	5	......
Arctic	Reindeer and Schlitz creeks.	Macklin divide	(a)	8	5	4.22	10	......
Irving Mining Co	Kougarok River	Columbia Creek.	1907	4.4	6	4.22	15	160
Taylor Creek Ditch Co.:								
North Star	Taylor Creek	Arctic Creek	1907	[b] 7	8	3.70	40	......
			1907	[c] 8	10	4.22	40	200
Cascade Mining and Ditch Co.	.....do	Claim 3	1907	6.25	5.5	4.22	12	110
T. T. Lane Co.:								
Henry Creek	Henry Creek	Homestake Creek.	(a)	10.25	6	3.17	15	210
	Lincoln Creek	Henry Creek intake.	(d)	3.25	......	......	......	......
Coffee Creek	Coffee Creek	Dahl Creek	1904	12.25	3–5	3.17	......	......
C. F. Merritt and others.	Arizona Creek	Benches on river	1905	2	4	3.17	2	185
Galvin & Buell	Coarse Gold Creek.	Two-bit Gulch	1907	5	8	4.22	25	300
Northwestern Development Co.	North Fork	......	(a)	6	7	3.17	20	......
Anderson Bros	Windy Creek	Anderson Gulch	1906	4	4	4.22	8	150
McKay Hydraulic Mining Co.	Turner Creek	Goose Creek	1907	16	4–5	4.22	8–10	......
Pittsburg-Dick Creek Mining Co.	Bryan Creek	Dick Creek	1907	6.5	6	4.22	15	170
	Quartz Creek	Bryan Creek divide.	(a)	8	8	4.22	20	[e] 350
Ottumwa Gold Mining Co.	Budd Creek	Below Windy Creek.	1907	8	9	3.70	30	160
	Million Creek	Windy Creek	1907	......	4	4.22	8	......

[a] Under construction.
[b] Intake to siphon.
[c] Siphon to Arctic Creek.
[d] Proposed.
[e] Above Bryan Creek ditch.

RELATIVE RUN-OFF OF DIFFERENT AREAS.

In order to afford a comparison of the run-off conditions in different areas, especially between those north and south of the Kigluaik Mountains, tables have been prepared showing the daily minima and monthly means for 1906 and 1907 in second-feet per square mile for the drainage areas investigated. The streams have been grouped into three classes—(1) those running in the foothills, having southern exposures and but few gulches in which snow is retained into the summer months; (2) streams rising in the mountains, having deep valleys and cirques with northern exposures, where snow is stored and held during the whole summer, and having a much heavier rainfall than streams at lower elevations; (3) streams of the Kougarok region. A study of the following tables shows several interesting points. In general, the nearer the stream lies to the central mountain mass of the Kigluaik Range, the greater is its run-off. The most notable exception to this rule is Hobson Creek. The flow of this stream comes from limestone springs, which are believed to draw some of their water from areas lying outside the surface drainage basin of the creek. North Star Creek, Fox Creek, and Nome River have a smaller minimum than adjoining streams whose basins have a similar character and elevation. This is probably due to their more direct southern exposure.

There is a striking difference, both in minimum and mean, between streams south of the mountains and those in the Kougarok region. This is due mostly to the small rainfall north of the mountains. Budd Creek draws all of its flow at low water from springs and so has a much larger minimum than other streams in the vicinity.

These tables may be used to estimate the run-off from other streams in Seward Peninsula, but such estimates must be made with extreme caution on account of the great difference in run-off in areas apparently similar.

The streams are not given in the order in which the descriptions appear in the text, but are arranged in general from east to west and from higher elevations to lower.

Minimum daily flow of streams in Seward Peninsula, 1906–7.

STREAMS RISING IN FOOTHILLS.

Stream.	Elevation.	Drainage area.	1906.			1907.		
			Date.	Minimum flow.	Minimum run-off per square mile.	Date.	Minimum flow.	Minimum run-off per square mile.
	Feet.	*Sq. miles.*		*Sec.-ft.*	*Sec.-ft.*		*Sec.-ft.*	*Sec.-ft.*
Iron Creek below mouth of Canyon Creek.	450	50	Aug. 14	17.1	0.34	Aug. 11–14	33	0.66
Eldorado River below mouth of Venetia Creek.	400	51	Aug. 14	44	.86			
Jett Creek	800	1.4	Sept. 10	[a] 4.2	3	Sept. 23	2.9	1.3
Copper Creek	800	.85	Aug. 11	.8	.94			
Nugget Creek	785	2.1	June 28	[b] .96	.46	Aug. 10–11	2.8	1.3
David Creek	590	4.3	Aug. 19	3.3	.77	Sept. 30	8.3	1.9
Dorothy Creek	500	2.7	Aug. 18	2.9	1.1			
Hobson Creek	500	2.6	July 4	10.5	[c] 4	Aug. 19	14.3	5.5
Slate Creek (tributary to Stewart River).	700	2.1	Aug. 19	2.2	1.05			
Stewart River	400	36	Aug. 19	11.4	.32			
Snake River	40	69				Aug. 12	77	1.1
Penny River	120	19	Aug. 1	[a] 36	1.9	Aug. 15	33	1.7

[a] Lowest measurements obtained; the flow was less on certain dates.

[b] The lowest flow later in 1906 was 3 second-feet, or 1.4 second-feet per square mile, on August 11.

[c] The flow of Hobson Creek is from large limestone springs whose catchment area may not coincide with the surface watershed.

Minimum daily flow of streams in Seward Peninsula, 1906–7—Continued.

STREAMS RISING IN KIGLUAIK MOUNTAINS.

Stream.	Elevation.	Drainage area.	1906.			1907.		
			Date.	Minimum flow.	Minimum run-off per square mile.	Date.	Minimum flow.	Minimum run-off per square mile.
	Feet.	*Sq. miles.*		*Sec. ft.*	*Sec. ft.*		*Sec. ft.*	*Sec. ft.*
North Fork Grand Central River near ditch intake.	750	5.4	July 1	23	4.3			
West Fork Grand Central River at ditch intake.	850	5.4	Sept. 15–17	19	3.5	July 29	28	5.2
Crater Lake outlet	925	1.8	Sept. 15–17	3.1	1.7	Sept. 22–23	3.5	1.9
Thompson Creek	720	2.5	Sept. 16–17	5	2	Sept. 22–23	5	2
Grand Central River below forks.	690	14.6	Sept. 16–17	47	3.1	Aug. 15	72	4.9
Grand Central River below Nugget Creek.	455	39	Sept. 16–17	90	2.3			
Grand Central River between station below forks and station at Nugget Creek.		24.4	Sept. 16–17	43	1.76			
Kruzgamepa River	442	81	Aug. 19 and Sept. 17.	175	2.16	Oct. 5	178	2.2
Crater Creek	550	11	Sept. 16–17	39	3.5			
Fox Creek	550	11	Aug. 16	17.3	1.6			
Nome River	575	15	Aug. 5	20	1.3	Aug. 15	16	1.1
Buffalo Creek	800	4.4	Aug. 3	9.1	2.1			
Sinuk River	770	[b] 6.2	Aug. 3	20	3.2	Aug. 15	[a] 22	2.7
North Star Creek	900	2.3	Aug. 10	2.9	1.26	Aug. 7	[a] 4	1.7
Windy Creek	650	12	Aug. 3	32	2.7	Aug. 15	[a] 32	2.7

[a] Minimum in midseason.

[b] 8.2 after August 1, 1907.

STREAMS IN THE KOUGAROK REGION.

Stream.	Elevation.	Drainage area.	1906. Date.	1906. Minimum flow.	1906. Minimum run-off per square mile.	1907. Date.	1907. Minimum flow.	1907. Minimum run-off per square mile.
Kougarok River at Homestake intake.		44				Aug. 13	3.2	0.07
Kougarok River above Coarse Gold Creek.		250				Aug. 9–12	16	.06
Taylor Creek at Cascade intake.		74				Aug. 14	3.9	.05
Henry Creek at mouth.		50				Aug. 13	6.8	.14
North Fork above Eureka Creek.		66				Aug. 15	9.6	.15
Noxapaga River		340				Aug. 16	62	.18
Turner Creek		13				Aug. 15	.7	.05
Budd Creek		58				Aug. 21	25	.43

Mean run-off, in second-feet per square mile, at gaging stations, 1906.

Station.	Drainage area.	July 1-31.	July 1-4 and 11-31.	Aug. 1-31.	Sept. 1-30.	Sept. 1-18.
	Sq. mi.					
North Fork of Grand Central River:						
Near ditch intake	5.4	....	[a] 7.53	6.80	....	5.85
At pipe intake	2.3	....	....	11.9	....	9.65
West Fork of Grand Central River:						
At ditch intake	5.4	....	10.3	6.02	....	4.72
At pipe intake	2.8	....	9.64	4.96	....	3.36
Crater Lake outlet	1.8	....	10.8	6.56	....	2.89
Thompson Creek	2.5	....	8.20	6.64	....	3.04
Grand Central River below forks	14.6	....	8.36	5.84	....	4.25
Grand Central River below Nugget Creek	39	....	....	[a] 4.42	....	3.36
Kruzgamepa River at outlet of Salmon Lake	81	7.05	....	3.20	5.63	3.05
Between Grand Central River below the forks and Kruzgamepa River stations	66	....	....	2.62	....	2.79
Nome River at Miocene intake	15	3.43	2.71	3.36	4.29	....

[a] Approximate.

Mean run-off, in second-feet per square mile, at gaging stations, 1907.

STREAMS RISING IN FOOTHILLS.

Station.	Drainage area.	July 1-31.	July 8-31.	August.	Sept. 1-30.	Sept. 1-23.
	Sq. miles.					
Jett and Copper creeks	2.25	7.69	....	3.16	4.27	....
Nugget Creek	2.1	2.71	....	2.95	5.24	....
David Creek	4.3	7.49	....	3.30	4.81	....
Hobson Creek	2.6	8.69	....	6.58	7.35	....
Snake River	69	2.56	....	1.56	....	....
Penny River	19	4.14	....	3.11	3.74	....

STREAMS RISING IN KIGLUAIK MOUNTAINS.

North Fork Grand Central River:						
At the forks	6.9	....	7.06	8.42	....	9.38
At pipe intake	2.3	....	16.9	18.9	....	20.2
West Fork Grand Central River:						
At the forks	7.7	....	11.0	10.5	....	13.0
At ditch intake	5.4	....	11.1	9.30	....	9.38
At pipe intake	2.8	....	9.43	6.29	....	7.32
Crater Lake outlet	1.8	....	13.6	14.4	....	11.7
Thompson Creek	2.5	....	16.9	10.8	....	9.12
Kruzgamepa River at outlet Salmon Lake	81	6.77	....	4.14	5.89	....
Nome River at Miocene intake	15	4.81	....	2.19	3.89	....
Sinuk River	[a] 6.2	8.44	....	5.49	....	6.55
North Star Creek	2.3	6.43	....	3.61	....	3.87
Windy Creek	12	7.62	....	4.93	....	5.68

[a] 8.2 after August 1.

STREAMS IN THE KOUGAROK REGION.

Station.	Drainage area.	July 15-31.	August.	Sept. 1-20.
Kougarok River:	*Sq. miles.*			
At Homestake intake	44	0.28	0.52	1.80
Above Coarse Gold Creek	250	.27	.56	1.55
Taylor Creek at Cascade intake	74	.40	.73	1.61

THE FAIRHAVEN PRECINCT.

By Fred F. Henshaw.

INTRODUCTION.

The Fairhaven precinct, comprising a large area in northeastern Seward Peninsula, has been a producer of placer gold since 1901 and promises to be more important in the future. No stream-gaging work has been done in this district, and it has not been visited by any member of the Geological Survey since 1903. The following notes concerning the water supply and the hydraulic developments that have been carried on during the last two seasons have been compiled from reliable sources.

FAIRHAVEN DITCH.

The Fairhaven ditch was built during 1906 by the Fairhaven Water Company. It takes its water supply from Imuruk Lake, the source of Kugruk River. A dam about 500 feet long has been constructed across the outlet of the lake to conserve the run-off.

The upper section of the ditch is 17 miles long, the first 8 miles of which is through a lava formation. The water is dropped into upper Pinnell River, and flows down this stream for about 4 miles. The lower section takes the water from Pinnell River on its right bank and extends for 23 miles to Arizona Creek, where a head of 500 feet is obtained. The ditch is 11 feet wide on the bottom and has a grade of 5 feet to the mile.

The dam across Imuruk Lake was closed August 16, 1906, and remained so until August, 1907, no water being carried in the ditch in the meantime. The water surface of the lake rose 26 inches during this period. The area of the lake is 30 square miles and that of the drainage basin 99 square miles. The run-off was therefore 41,600 acre-feet, equivalent to 7.9 inches in depth over the entire drainage area. This would furnish 58 second-feet for one year, 210 second-feet for one hundred days, or 263 second-feet for eighty days. The snowfall during the winter of 1906–7 was heavier than usual, so that the water supply for other years may be less than this.

The above information was furnished by W. R. Hoffman, who had charge of the construction of the Fairhaven ditch.

CANDLE DITCH.

The Candle ditch was built during 1907 by the Candle-Alaska Hydraulic Gold Mining Company to furnish water for mining on Candle Creek. It has a total length of 33.6 miles, a bottom width of 9 feet, and a grade of 3.69 feet per mile. The estimated capacity is 35 second-feet. It takes its supply from the western tributaries of Kiwalik River. The present intake of the ditch is on Glacier Creek. The water is carried across Dome Creek in a siphon 2,250 feet long, composed of 28-inch pipe; across Bonanza Creek in 900 feet of 32-inch pipe; and across Eldorado Creek in a siphon 12,100 feet long, composed of equal lengths of 35½, 37½, and 39½ inch pipe. Eldorado Creek will be tapped with a lateral ditch about 6 miles long. An extension 8.1 miles long of 6-foot ditch will be built to Gold Run. It will also be possible to divert the flow from the headwaters of First Chance Creek, a tributary of Koyuk River, over a low divide into Gold Run.

The fall obtained is 250 feet at the mouth of Candle Creek and 132 feet at the mouth of Patterson Creek. The surveyed line crosses Candle Creek about 1 mile above the mouth of Willow Creek. Candle Creek was nearly dry during 1907, the flow some of the time being less than half a second-foot.

The above information was furnished by W. L. Leland.

BEAR CREEK DITCH.

A ditch was built in 1907 on Bear Creek, a tributary of the West Fork of Buckland River. It has its intake below the mouth of May Creek, and extends along the right bank to Split Creek, diverting Eagle, Polar, and other small creeks. The ditch has a length of about 6 miles, a bottom width of 6 feet, and a grade of 4 feet to the mile. The head obtained at the lower end is about 200 feet.

THE FAIRBANKS DISTRICT.

By C. C. Covert.

DESCRIPTION OF AREA.

The area known as the Fairbanks district extends about 60 miles to the north of Fairbanks and is from 40 to 50 miles in width. The greater part of the region lies in the lower Tanana basin, but a portion to the northwest is directly tributary to the Yukon. Generally speaking, it embraces three divisions—a low, broad alluvial plain, a moderately high plateau, and a mountain mass.

The low, broad plain forms the bottom lands of the lower Tanana Valley, which in this section is divided into several parts by the Tanana and its slough-like channels. The main slough starts near the mouth of Salcha River, about 30 miles above Fairbanks, where it diverts a portion of the Tanana waters. Its course is along the foothills of the plateau to the north, and it receives Chena River about 7 miles above Fairbanks. The plain is swampy in character and is well covered with timber along the banks of the streams. In the vicinity of Fairbanks it has a general elevation of about 500 feet above sea level.

The plateau is drained by streams tributary to Tanana River, which flow through rather broad, unsymmetrical valleys, most of which extend in a northeast-southwest direction. Their bottom lands range in elevation from 500 to over 2,000 feet above sea level, and the dividing ridges are in general 2,000 to 3,000 feet above the stream beds. That portion of the plateau which comes under discussion in this report is drained principally by Little Chena and Chatanika rivers. The upper region of these drainage basins is crosscut by a zigzag range, which separates the Yukon from the Tanana drainage.

The mountain mass to the north of this plateau forms what might be termed the apex of the divide between the Tanana and the Yukon drainage basins. It rises to an altitude of 4,000 to 5,000 feet above sea level and its corrugated slopes are drained principally by tributaries to Yukon River.

All drainage areas tributary to the Tanana are similar in character. The streams have little slope except near their source. Wide, gravelly beds of a shifting nature and tortuous courses keeping to one side of the valley are marked characteristics. The channels usually have rather steep banks that form approaches to broad, level bottom lands which extend from 1,000 to 4,000 feet or more before they meet the abrupt slopes of the dividing ridges. The drainage basins are from 4 to 15 miles wide and are well cut up by small tributary streams flowing through deep and narrow ravines.

A large portion of the area is covered with a thick turf known as tundra, which is wet, spongy, and mossy and ranges in thickness from 6 inches to 2 feet. In some localities this is meadow like, producing a rank growth of grass and a variety of beautiful wild flowers. Underneath this tundra ground ice is found in many places, particularly on the northern slopes, where the soil is scanty and there is little timber or other vegetation. The soil of the southern slopes is, for the most part, gravelly clay, underlain by a mica schist which affords suitable ground for ditch construction. When stripped of its mossy covering, the sun rapidly thaws it so that the plow and scraper can be used to advantage.

Above an altitude of 2,000 to 2,200 feet practically the only vegetation is a scrubby, bushy growth which attains a height of 2 to 4 feet. In general the country below this altitude is timbered by spruce and birch, with scattered patches of tamarack and willow along the banks of the smaller streams. The timber increases in density and size as the river bottoms are approached. There the prevailing growth is spruce, much of which attains diameters of 18 to 24 inches.

The Fairbanks mining district lies between Little Chena and Chatanika rivers. It embraces an area of some 500 square miles and extends about 30 miles to the north of Fairbanks, which is situated on Chena Slough nearly 12 miles above its confluence with the Tanana. The producing creeks in general rise in a high rocky ridge, of which Pedro Dome, with an elevation of about 2,500 feet, is the center. At least half of the mines are located at an elevation of over 800 feet, and 25 per cent over 1,000 feet, above sea level.

The field work during 1907 in the Fairbanks district was carried on from June 20 to September 15. Owing to the lack of adequate funds the work was largely that of reconnaissance. However, the keeping of systematic records on some of the more important streams was made possible through the hearty cooperation of people who were interested.

After making a careful study of the general topographic conditions of the mining district and surrounding country, it was decided to establish a few regular stations, at the most convenient points in the larger drainage areas, and study the daily run-off, during the open season from records thus obtained.[a] This plan afforded greater opportunity for procuring comparative data than that of covering a larger territory in a less definite way. In this country without storage, daily records are an important factor, and such records could not have been obtained over an extended area. Outside of the producing creeks the country is practically a wilderness, and it is almost impossible to get observations, other than those made on the occasional visits of the engineer. No daily or even weekly records in such areas could have been assured and the results obtained from the occasional measurements would have furnished no comprehensive idea as to the actual daily run-off of the streams throughout the open season.

CONDITIONS AFFECTING WATER SUPPLY.

Stream flow in the Fairbanks district is affected by melting of accumulated snow and ice, summer rains, and melting of ground ice. In this district the break-up begins about the middle of April and the rise in the streams commences about the middle of May and continues intermittently until May 30, or thereabouts, when the maximum discharge occurs. The table on page 109 shows the daily gage height of Chena Slough at Fairbanks during the open season of 1907. A. D. Gassaway, of the Chatanika Ditch Company, estimated the maximum flow of Chatanika River near the mouth of Faith Creek at about 1,250 second-feet and stated that this discharge occurred about May 30. After that date the flow gradually decreased until the minimum stage was reached, about July 10.

The precipitation records kept at Fairbanks since 1905 (see table p. 143) show that snowfall in this section amounts to about 40 inches. On account of the frozen ground and the steady cold weather, very little of this snow runs off before the spring break-up. What run-off there is during the winter season, especially in the upper basins, is accumulated in the glacial ice formed in the stream beds. This ice does not entirely disappear before the middle or last of July.

There are few data regarding rainfall in this section. Records have been kept at Fairbanks since 1905 and in connection with the investigations of stream flow the Geological Survey established four stations in 1907. The daily and monthly rainfall at these points is given in the tables on pages 140 to 141. A comparison of the 1907 rainfall records throughout Alaska, especially those of the interior, with records previously obtained will show that the season was a comparatively normal one.

---

[a] For explanation of data and methods of work see p. 9.

The melting of frozen ground affords a slight additional supply of water to the streams. The frozen muck and ground ice, which carry a large percentage of water, are well protected by a thick coat of moss, through which it is difficult for the heat of the summer sun to penetrate. As the season advances the imprisoned moisture is liberated through the combined influence of abundant sunshine and frequent warm rains. This gradual thawing of frozen ground is made noticeable not only by the increase of the daily flow of the streams, but also by the condition of the trail and the increased depth to which one sinks when traveling over the tundra. On the northern slope and in the deep canyons, which are protected from the rays of the sun, the frozen ground never thaws more than a few inches, even during July and August, when the sun shines nearly twenty-four hours a day.

Owing to the shallow depth to which the ground thaws, the prevailing mossy covering affords the only ground storage for rainfall in this country. This covering is filled with seepage from ground thaw and consequently any increase in the water supply, through rainfall, finds its way to the streams in a very short time over the underground ice and steep slopes of the drainage basins, causing streams to rise and fall very rapidly. (See fig. 2.) Because of this lack of ground storage the streams depend largely on rainfall for their supply, after the snow and ice have disappeared in the spring break-up. May, June, and July are invariably months of slight rainfall in the interior (see p. 140) and the streams soon reach a very low stage. Yet this is the most important period for the miner. The long hours of daylight and the warm weather afford favorable opportunities for mining and sluicing, but the abundant supply of water needed for this purpose is often lacking.

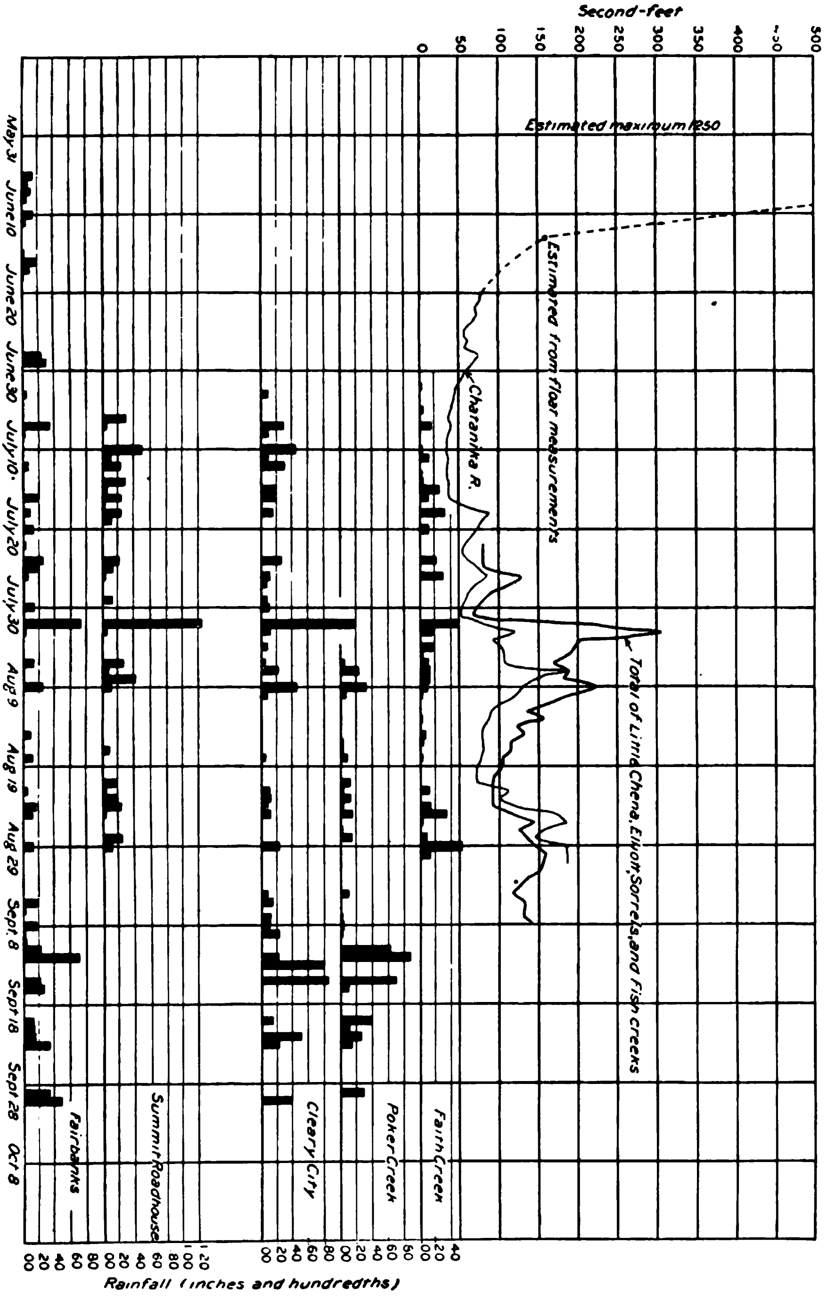


FIG. 2.—Diagram showing flow of Chatanika River and total flow of Little Chena River and its tributaries in 1907.

GAGING STATIONS.

The following list gives the points in the Fairbanks district at which gages were established or discharge measurements made in 1907. The numbers refer to Pl. IX:

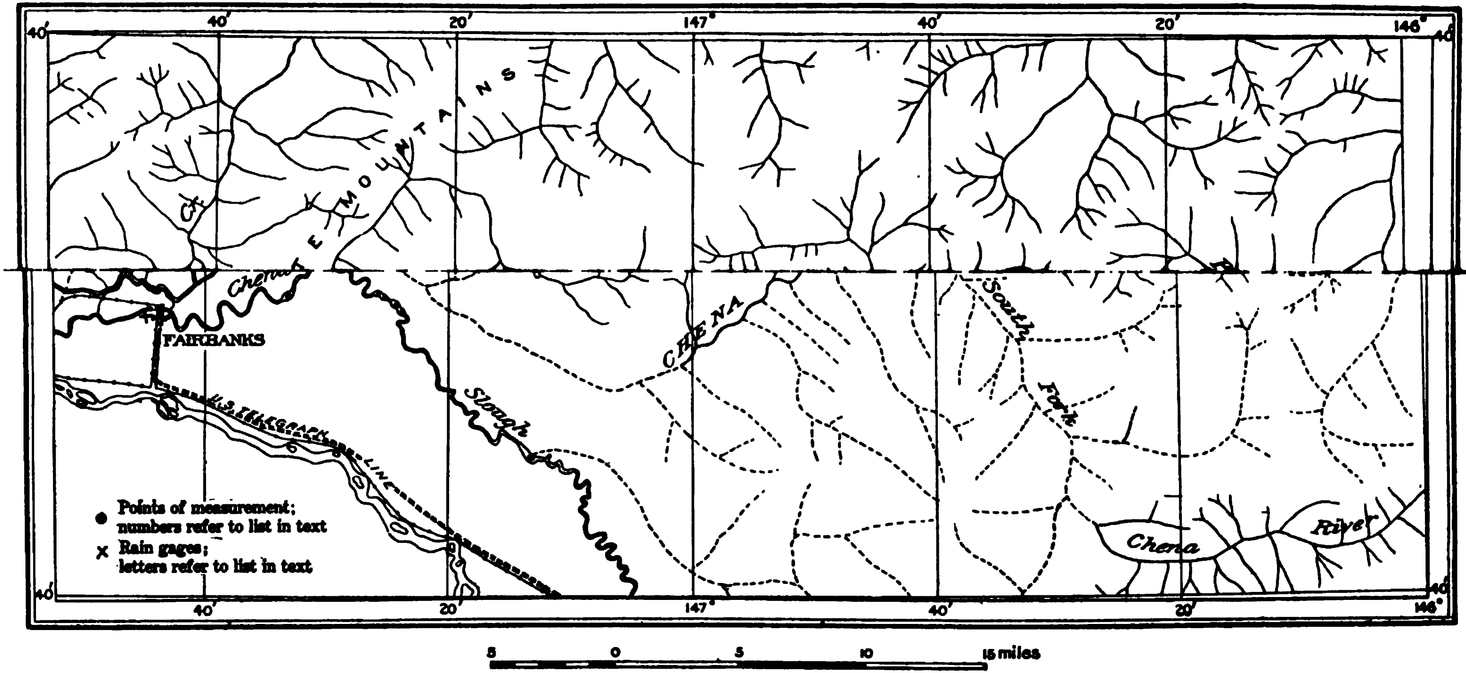
Gaging stations in Fairbanks district.

1. Little Chena River about 2 miles above Elliott Creek.
2. Elliott Creek above mouth of Sorrels Creek.
3. Sorrels Creek above mouth.
4. Fish Creek above Fairbanks Creek.
5. Bear Creek near mouth of Tecumseh Creek.
6. Fairbanks Creek.
7. Miller Creek near mouth.
8. Miller Creek below Heim Creek.
9. Miller Creek above Heim Creek.
10. Charity Creek 1 mile above mouth of Hope Creek.
11. Hope Creek near mouth of Zephyr Creek.
12. Faith Creek at weir near mouth.
13. McManus Creek above Montana Creek.
14. McManus Creek below Montana Creek.
15. McManus Creek 1 mile below Idaho.
16. McManus Creek 500 feet above mouth of Smith Creek.
17. McManus Creek below mouth of Smith Creek.
18. McManus Creek at mouth.
19. Smith Creek below mouth of Pool Creek.
20. Smith Creek above mouth of Pool Creek.
21. Pool Creek above mouth.
22. McManus Creek at weir near mouth.
23. Chatanika River below Faith and McManus creeks.
24. Boston Creek, elevation 800 feet.
25. McKay Creek, elevation 800 feet.
26. Belle Creek, elevation 800 feet.
27. Crooked Creek near mouth.
28. Kokomo Creek near mouth.
29. Poker Creek near mouth.
30. Poker Creek near elevation 800 feet.
31. Little Poker Creek above mouth.
32. Caribou Creek above mouth of Little Poker Creek.
33. Chatanika River below mouth of Poker Creek.
34. Cleary Creek near Cleary.
35. Little Eldorado Creek above trail to Dome.
36. Dome Creek near Dome.
37. Goldstream Creek at claim 6 below.
38. Fox Creek near elevation 900 feet.
39. Beaver Creek above mouth of East Branch.
40. East Branch Beaver Creek above mouth.
41. Nome Creek 1 mile above mouth.
42. Bryan Creek, elevation 1,800 feet.
43. Trail Creek about 4 miles above mouth.
44. Brigham Creek 1 mile above mouth.
45. Fossil Creek near mouth.

LITTLE CHENA RIVER DRAINAGE BASIN.

GENERAL DESCRIPTION.

The southern slope of the divide between the Chatanika and Chena drainage basins, from the headwaters of Smith and Flat creeks to Pedro Dome, a distance of about 25 miles, is drained by Little Chena River and its tributaries, Elliott and Fish creeks. The drainage basin is irregular in shape and has a network of small, ramifying streams with steep, precipitous slopes in their upper drainage. The upper portion of the main stream is also steep, having a fall of 100 to 150



MAP SHOWING LOCATION OF GAGING STATIONS IN FAIRBANKS REGION.

feet to the mile. This slope decreases rather abruptly to about 18 feet to the mile in the vicinity of Elliott and Fish creeks.

The general course of the stream above the confluence of Fish Creek is through a rather broad, unsymmetrical valley. Below Fish Creek the river takes the center of a deep, narrow channel for about 8 miles to the point where Anaconda Creek, an important tributary from the left, enters. Below this point the valley gradually widens until the stream enters the lowlands tributary to Chena River, into which it empties 6 or 8 miles above the confluence of Chena Slough. Through this slough it discharges its waters into the Tanana near the town of Chena.

In the low-water period the stream has a channel width of 30 to 75 feet and flows from side to side of a broad, gravelly bed ranging from 100 to 300 feet in width. The channel is defined by steep, alluvial banks forming the approach to the heavily timbered bottom lands of the river valley which prevail above the confluence of Fish Creek. In the high-water stages the broad river bed is filled to its banks and often overflows them. During this stage the river seeks numerous smaller channels that surround heavily wooded islands.

The greater part of the drainage basin is well covered with timber, that in the uplands, on the slopes and smaller divides, consisting of spruce, birch, and poplar, suitable only for fuel and cabin purposes. In the lower valleys and creek bottom lands the prevailing growth is spruce, much of which is suitable for milling purposes.

The area is invariably covered with the conventional moss, but here and there outcroppings of limestone, mica schist, and gravel are found on the slopes. In the creek valleys the mossy covering is usually underlain with frozen muck and glacial ice. Numerous swamp areas occur near the river banks, and these, together with the heavy growth of timber, make travel very difficult.

Gaging stations were established on Fish Creek above the mouth of Fairbanks Creek, on Elliott Creek above the mouth of Sorrels Creek, on Sorrels Creek above its mouth, and on the Little Chena about 2 miles above the mouth of Elliott Creek. Much credit is due Sherman White, the observer, for his faithful work in making approximately daily observations at each of these stations.

A project is under way to collect the waters from the different tributaries, at an elevation of about 900 feet, and to convey the supply by ditch line to a point in the lower drainage area, on the right bank of the Little Chena, where a fall of nearly 200 feet can be obtained. A portion of the water so collected is to be used in developing electric power for transmission to the producing creeks, and the excess water will be carried by ditch line to Smallwood and Nugget creeks and used for mining purposes.

The following table gives the horsepower (80 per cent efficiency) per foot of fall that may be developed at different rates of discharge, and shows the number of days on which the discharge and the corresponding horsepower were respectively less than the amounts given in the columns for "discharge" and "horsepower."

Discharge and horsepower table for Little Chena River and tributaries, 1907.

Discharge.[a]	Horsepower (80 per cent efficiency) per foot fall.	Days of deficient discharge, July 22 to Sept. 10.	Discharge.[a]	Horsepower (80 per cent efficiency) per foot fall.	Days of deficient discharge, July 22 to Sept. 10.
Sec.-ft.			*Sec.-ft.*		
66	6	0	154	14	35
88	8	7	176	16	42
110	10	15	198	18	45
132	12	23	220	20	48

[a] This includes the flow of Little Chena, Elliott, Sorrels, and Fish creeks.

Drainage areas of Little Chena River basin.[a]

Stream and location.	Area.	Total area.
	Sq. miles.	*Sq. miles.*
Little Chena River above gaging station	79.0	79.0
Little Chena River from gaging station to mouth of Elliott Creek	3.6	82.6
Elliott Creek above gaging station	13.8	
Sorrels Creek above gaging station	21.0	
Elliott Creek from gaging station to mouth	3.8	
Total Elliott Creek	38.6	121.2
Little Chena River from mouth of Elliott to Fish Creek	6.0	127.2
Fish Creek above Bear Creek	23.6	
Bear Creek above mouth	12.0	
Fish Creek from Bear Creek to gaging station	3.6	
Fish Creek above gaging station	39.2	
Fairbanks Creek above mouth	20.5	
Fish Creek, Fairbanks Creek to Miller Creek	13.0	
Miller Creek above mouth	16.5	
Fish Creek from Miller Creek to mouth	1.0	
Total Fish Creek	90.2	217.4
Little Chena from mouth of Fish Creek to Anaconda Creek	30.7	248.1
Anaconda Creek above mouth	43.3	291.4
Little Chena from Anaconda Creek to mouth	113.2	404.6

[a] From reconnaissance map Yukon-Tanana region, Fairbanks quadrangle.

CHENA SLOUGH AT FAIRBANKS.

Near the mouth of Salcha River a portion of the Tanana waters are diverted through a sloughlike channel about 50 miles in length, that separates the broad flat lands to the right into two parts. The channel receives the drainage of the plateau to the north and about midway in its course Chena River enters. Below this point the channel is known as Chena Slough. It affords a passageway for the Tanana steamers from its mouth near Chena to Fairbanks, 12 miles above, except in times of low water, when the cargoes are transferred at Chena to the Tanana Mines Railroad.

A gage fastened to the highway bridge in Fairbanks is read twice each day during the open season by employees of the Northern Navigation Company.

Daily gage height, in feet, of Chena Slough near Fairbanks, Alaska, 1907.

Day.	May.	June.	July.	Aug.	Sept.
1		5.3	2.4	3.2	1.9
2		5.2	2.6	3.4	1.8
3		5.1	2.8	3.9	1.6
4		4.6	2.8	3.8	1.5
5		4.0	2.6	3.8	1.4
6		4.8	2.1	3.9	1.4
7		5.6	2.2	4.0	1.4
8		4.8	2.3	4.0	1.4
9		4.4	2.2	4.1	1.5
10		4.0	2.0	4.1	1.8
11		3.9	2.1	4.1	2.0
12		4.1	2.1	3.9	2.0
13		4.1	2.3	3.6	3.3
14		3.9	2.6	3.6	5.3
15		3.8	2.9	3.6	4.6
16		3.5	3.1	3.5	4.3
17		3.6	3.0	3.4	6.1
18		3.8	2.9	3.3	6.0
19		3.1	2.7	3.1	4.8
20		2.6	2.6	3.1	4.0
21		2.1	2.8	3.1	3.8
22		2.0	3.1	3.3	3.9
23		2.8	3.4	3.1	4.0
24	5.6	1.5	3.5	3.0	
25	5.8	1.4	3.6	2.5	
26	5.6	1.5	3.6	2.2	
27	5.2	1.2	3.3	2.1	
28	4.6	1.3	3.1	2.0	
29	4.1	1.5	3.0	1.8	
30	5.5	2.0	3.0	1.8	
31	5.9		3.0	1.8	

LITTLE CHENA RIVER ABOVE MOUTH OF ELLIOTT CREEK.

A gaging station was established on Little Chena River about 2 miles above the mouth of Elliott Creek July 22, 1907. At this point the channel is from 30 to 50 feet in width during low and medium stages. It has a gravelly bed and is fairly straight for about 100 feet. A stake graduated to feet and tenths was driven near the left side and daily readings were taken.

Discharge measurements of Little Chena River above mouth of Elliott Creek, 1907.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq.-ft.*	*Feet.*	*Sec.-ft.*
July 22	23.5	26.6	0.60	44.2
July 24	23.5	26.7	.565	39.7
August 4	40.0	42.2	1.10	113
August 5	33	37.2	1.05	103
August 20	25	28.0	.73	56.7

Daily gage height and discharge of Little Chena River above mouth of Elliott Creek, 1907.

[Elevation, 800 feet; drainage area, 79 square miles.]

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.7	53	1.0	95
2			1.3	157	.9	80
3			1.1	113	.9	80
4			1.1	113	.8	66
5			1.1	113	.9	80
6			1.0	95	.95	88
7			1.05	104	.95	88
8			1.1	113	1.0	95
9			1.2	134		95
10			1.1	113	1.0	95
11			1.0	95		
12			.9	80		
13			1.0	95		
14			.8	66		
15			.9	80		
16			.8	66		
17				66		
18				60		
19				60		
20			.7	53		
21			.7	53		
22	0.60	42	.7	53		
23		42	.7	53		
24	.60	42	.7	53		
25	.60	42		73		
26	.90	80	1.0	95		
27	.80	66	.9	80		
28	.70	53	.9	80		
29	.60	42		88		
30	.60	42	1.0	95		
31	.60	42	1.0	95		
Mean		[a]49.3		85.4		[b]86.2
Run-off per square mile		.625		1.08		1.09
Run-off, depth in inches		.23		1.24		.40

[a] July 22-31.

[b] September 1 to 10.

ELLIOTT CREEK ABOVE MOUTH OF SORRELS CREEK.

Elliott Creek takes the drainage from the southern slope of Twin Butte Hills, in the Chatanika divide, and flows in a southerly direction, discharging its waters and those of Sorrels Creek, its tributary, into the Little Chena about 4 miles above the mouth of Fish Creek.

The drainage area is steep in its upper reaches and well timbered in the creek bottom. The stream flows in a narrow channel, rather deeply cut, and the banks are lined with willow and small spruce.

A gaging station was established about half a mile above the mouth of Sorrels Creek July 22, 1907, and regular readings were taken.

Discharge measurements of Elliott Creek above mouth of Sorrels Creek, 1907.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
July 23	9.5	6.4	1.6	5.1
August 5	12.0	9.6	1.85	13.8
August 20	10.1	6.98	1.615	7.1

Daily gage height and discharge of Elliott Creek above mouth of Sorrels Creek, 1907.

[Elevation, 800 feet; drainage area, 13.8 square miles.]

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.7	9.0	1.8	12.3
2			2.1	23	1.8	12.3
3			2.1	23	1.7	9.0
4				17.2	1.7	9.0
5			1.8	12.3	1.7	9.0
6			1.8	12.3		9.0
7				12.3		9.0
8			1.8	12.3	1.7	9.0
9			1.9	15.6		10.0
10			1.8	12.3		12.0
11			1.8	12.3		
12			1.7	9.0		
13			1.8	12.3		
14			1.8	12.3		
15			1.7	9.0		
16			1.7	9.0		
17				9.0		
18				7.4		
19			16.5	7.4		
20			1.6	5.8		
21			1.6	5.8		
22	1.6	5.8	1.6	5.8		
23	1.6	5.8	1.6	5.8		
24	1.6	5.8	1.6	5.8		
25	1.6	5.8		7.4		
26	1.7	9.0	1.7	9.0		
27	1.7	9.0	1.7	9.0		
28	1.6	5.8	1.8	12.3		
29	1.6	5.8		12.3		
30		4.1		12.3		
31	1.5	2.5	1.8	12.3		
Mean		[a] 5.9		11.0		[b] 10.0
Run-off per square mile		0.43		0.797		0.724
Run-off, depth in inches		.16		.92		.27

[a] July 22 to 31.

[b] September 1 to 10.

SORRELS CREEK.

Sorrels Creek, a tributary to Elliott Creek about 3 miles above its mouth, rises in the Chatanika divide, to the west of Flat Creek, and flows westward along this divide for about 5 miles, then, by an abrupt bend to the left, it takes a southerly course for about 6 miles to

Elliott Creek. The stream flows in a narrow irregular channel, rather deeply cut in the mucklike bottom lands, and is well hidden from view by the masses of spruce and willow along its banks.

A gaging station was established on this stream about one-half mile above its mouth July 23, 1907, and regular readings were taken.

Discharge measurements of Sorrels Creek near mouth, 1907.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
July 23	11.0	9.95	1.00	10.3
August 5	17.0	16.8	1.40	28.2
August 20	12.0	10.7	1.02	12.0

Daily gage height and discharge of Sorrels Creek near mouth, 1907.

[Elevation, 800 feet; drainage area, 21 square miles.]

Day.	July.		August.		September.		Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	......	......	1.1	14.7	1.2	19.0	20	......	......	1.0	10.3	......	......
2	......	......	1.4	27.8	1.2	19.0	21	......	......	1.0	10.3	......	......
3	......	......	1.4	27.8	1.1	14.7	22	1.0	10.3	1.0	10.3	......	......
4	......	......	1.5	32.1	1.1	14.7	23	1.0	10.3	1.0	10.3	......	......
5	......	......	1.35	25.6	1.1	14.7	24	1.0	10.3	1.0	10.3	......	......
6	......	......	1.3	23.4	......	14.7	25	1.0	10.3	......	12.5	......	......
7	......	......	......	23.4	......	14.7	26	1.1	14.7	1.1	14.7	......	......
8	......	......	1.3	23.4	1.1	14.7	27	1.1	14.7	1.1	14.7	......	......
9	......	......	1.4	27.8	......	14.7	28	1.0	10.3	1.2	19.0	......	......
10	......	......	1.3	23.4	......	19.0	29	1.0	10.3	......	19.0	......	......
11	......	......	1.3	23.4	......	......	30	......	8.2	......	19.0	......	......
12	......	......	1.2	19.0	......	......	31	.9	6.0	1.2	19.0	......	......
13	......	......	1.2	19.0	......	......							
14	......	......	1.2	19.0	......	......	Mean		[a]10.5	......	18.2	......	[b]16
15	......	......	1.1	14.7	......	......							
16	......	......	1.1	14.7	......	......	Run-off per square mile		0.500	......	0.867	......	.762
17	......	......	......	14.7	......	......							
18	......	......	......	12.5	......	......	Run-off depth in inches		.19	......	1.00	......	.28
19	......	......	......	10.3	......	......							

[a] July 22-31.

[b] Sept. 1-10.

FISH CREEK ABOVE MOUTH OF FAIRBANKS CREEK.

Fish Creek rises in the high ridge at the head of Goldstream Creek and flows in a northeasterly direction through an irregularly formed valley. About 14 miles below its source it makes an abrupt bend to the right, flowing around the point of a rather steep divide that separates its drainage from that of the Little Chena, into which it discharges about 2 miles below this bend. Its principal tributaries are Solo, Bear, Fairbanks, and Miller creeks, all from the left. These streams are rather steep in their upper courses but rapidly lessen in slope as Fish Creek Valley is approached. Fish Creek has a tortuous course and closely follows the right side of the valley, having a rather broad, marshy bottom land on the left.

A gaging station was established a short distance above Fairbanks Creek July 22, 1907 (see Pls. IX; XI, *B*), and regular readings were taken.

Discharge measurements of Fish Creek above mouth of Fairbanks Creek, 1907.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
July 21	9.5	10.4	1.00	23.7
July 25	10.0	12.2	1.00	24.3
August 3	14.5	17.5	1.55	47.5
August 4	12.7	14.0	1.35	37.6
August 19	9.2	9.95	1.00	20.8

Daily gage height and discharge of Fish Creek above mouth of Fairbanks Creek, 1907.

[Elevation, 925 feet; drainage area, 39 square miles.]

Day.	July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			3.2	155	1.0	24
2			2.4	100	1.0	24
3			1.4	39	1.0	24
4			1.3	35	1.0	24
5				37	1.1	27
6			1.4	39		27
7			1.55	47		27
8			1.3	35	1.1	27
9			1.6	50	1.1	27
10			1.6	50	1.3	35
11				39		
12			1.2	31		
13			1.1	27		
14			1.1	27	2.6	[a] 115
15			1.1	27		
16			1.0	24		
17			1.0	24		
18				24		
19			1.0	24		
20				24		
21			1.0	24		
22	1.0	24	1.0	24		
23		24		24		
24		24	1.0	24		
25	1.0	24	1.1	27		
26	1.1	27	1.1	27		
27	1.0	24	1.0	24		
28	.9	21	1.0	24		
29	.9	21		27		
30	.8	18	1.2	31		
31	.8	18	1.1	27		
Mean		[b] 22.5		36.8		[c] 26.6
Run-off per square mile		.577		.944		.682
Run-off, depth in inches		.21		1.09		.25

[a] Not included in mean.
[b] July 22 to 31.
[c] Sept. 1 to 10.

BEAR CREEK.

Bear Creek rises in the high divide at the head of Goldstream Creek, flows eastward through a deep, narrow valley, and empties into Fish Creek about one-half mile above the gaging station. Measurements were made on this creek below the mouth of Tecumseh Creek as follows: July 20, 8.4 second-feet; August 22, 7 second-feet; drainage area, 12 square miles; run-off per square mile, 0.70 and 0.584 second-foot, respectively.

FAIRBANKS CREEK.

Fairbanks Creek rises on the eastern side of Pedro Dome, opposite the headwaters of Cleary Creek, and flows in an easterly direction for about 10 miles to Fish Creek. It is separated from Bear Creek on the right by a steep, high ridge, rising from 800 to 1,000 feet above the stream bed. The valley to the left has a more gradual slope and is drained by several small tributaries—Moose, Crane, Alder, Walnut, and Deep creeks. The stream has rather steep slopes in its upper course. Below Moose Creek the average fall is about 75 feet to the mile. The stream flows close to the dividing ridge on the east until it approaches the broad lowland near Fish Creek. The lower portion flows through a narrow, deep-cut channel, thickly lined with willow and spruce.

Discovery claim is located near Alder Creek. Mining operations are carried on from claim 9 above to claim 13 below. The pay streak follows closely to the stream channel down to claim 9 below, where it swings to the left limit. Above claim 2 below most of the work is by the open-cut method. Below this point it is underground by drifting. The following measurements were made in 1907, but owing to the unfavorable conditions they are approximate only:

Discharge measurements of Fairbanks Creek, 1907.

Date.	Elevation.	Discharge.
	Feet.	*Sec.-ft.*
June 24	1,300	1.4
Do	1,250	2.2
July 5	1,375	.72
July 20	1,400	1.3

MILLER CREEK.

Miller Creek rises in the southeasterly slope of Coffee Dome, and flows in a southerly direction, emptying into Fish Creek about 2 miles above its confluence with Little Chena River. It is about 6 miles long and flows through a narrow valley, draining an area of 16.7 square miles. The following discharge measurements were made in 1907:

Discharge measurements of Miller Creek, 1907.

Date.	Point of measurement.	Elevation.	Drainage area.	Discharge.	Run-off per square mile.
		Feet.	*Sq. miles.*	*Sec.-ft.*	*Sec.-ft.*
July 6	Near mouth	750	15	7.0	0.47
July 24	.....do	750	15	7.6	.51
August 20	.....do	750	15	8.0	.53
August 6	Below mouth of Heim Creek	790	10	8.0	.80
August 7	.....do	790	10	8.0	.80
Do	Above mouth of Heim Creek	800	6	4.9	.82

CHATANIKA RIVER DRAINAGE BASIN.

GENERAL DESCRIPTION.

Chatanika River is formed by the junction of Faith and McManus creeks, which drain the high ridge forming the divide between the lower Tanana and Yukon basins. The river flows through a long and rather narrow valley in a southwesterly direction and is tributary to the Tolovana from the east, about 30 miles above the confluence of that stream with the Tanana. Its course lies mostly to the western side of the valley, which is from one-half mile to 7 miles in width. The valley is about 80 miles in length and heavily covered with timber below an altitude of 1,800 to 2,000 feet. The river has a drainage area of approximately 1,300 square miles above its mouth.

From the junction of Faith and McManus creeks the stream flows in a winding course and has a shifting, gravelly bottom. In low and medium stages it flows in a series of pools and rapids and has a width of 75 to 200 feet, and during the high-water period it often seeks several channels and covers a width of 100 to 400 feet. This high-water channel is usually well defined by steep, alluvial banks ranging from 8 to 10 feet in height.

Below Poker Creek, a tributary from the right about 40 miles downstream from the junction, the valley widens and the bottom lands become marshy and swampy. Here, from the left, the Chatanika receives the drainage from Cleary, Eldorado, Dome, Vault, and other less important streams from the mining district proper. Below these tributaries the valley narrows to a gorgelike channel which it follows for about 10 miles. Below this gorge the dividing ridges disappear and the stream meanders through the low, swampy grounds to the north of Tanana River. About 10 miles from its mouth Goldstream Creek, its largest tributary, joins it from the left.

The average elevation of the divides in the upper drainage area of the Chatanika is between 3,000 and 4,000 feet above sea level, and the altitude of the ridges bounding the valley on the east and west is about 2,000 feet.

The tributary streams from the right are short and precipitous, flowing through V-shaped valleys; those from the left have less precipitous courses and broader valleys, and gradually lose themselves in the rather broad expanse of swamplike bottom lands which prevail on that side.

The altitude and drainage area of the upper Chatanika has attracted the attention of "outside" capital for some time. The general topography has seemed suitable for a possible water supply by ditch line to the mining district proper, and the favorable slope of portions of Faith and McManus creeks has made them attractive to the promoter for hydraulicking.

Several gaging stations were established in this drainage basin during 1907. In June A. D. Gassaway, general manager of the Chatanika Ditch Company, began the first records of actual stream flow in this section by establishing gaging weirs at the mouth of Faith and McManus creeks.

Through the courtesy of this company, the records are published on page 117 in this report.

FAITH CREEK.

Faith Creek, the right fork of Chatanika River, has its source in the southeasterly slope of the high ridges separating the Beaver and Birch Creek drainage basin from that of the Chatanika. It has a rather narrow, irregular valley, very steep in its upper course, and drains an area of 51 square miles.

The following measurements were made in its upper drainage basin July 11, 1907.

Hope Creek near the mouth of Zephyr Creek: Discharge, 7.7 second-feet; run-off, 0.42 second-foot per square mile.

Charity Creek about 1 mile above the mouth of Hope Creek: Discharge, 5.7 second-feet; run-off, 0.76 second-foot per square mile.

In the upper portion of the valley considerable glacial ice remains as late as the middle of July, especially in Charity Creek. Below the mouth of Deep Creek, a tributary from the right in the lower valley, there is a favorable reservoir site and with a moderate-sized dam a considerable amount of the flood waters could be stored.

The Chatanika Ditch Company established a gaging weir at the mouth of Faith Creek in 1907, and daily records were kept subsequent to June 21.

Daily discharge, in second-feet, of Faith Creek at weir near mouth, 1907.

[Elevation, 1,375 feet. Drainage area, 51 square miles.]

Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.
1	....	32.6	36.4	59.0	20	44.7	43.9	27.8	....
2	....	28.5	41.1	52.5	21	44.7	38.6	26.9	....
3	....	26.4	35.9	50.2	22	42.8	31.4	44.2	....
4	....	24.8	34.7	66.4	23	39.3	25.5	39.4	....
5	....	22.1	42.5	....	24	38.8	28.8	49.8	....
6	....	21.6	40.6	....	25	35.3	26.4	62.8	....
7	....	22.0	87.4	....	26	36.5	61.0	82.6	....
8	....	20.8	62.7	....	27	34.4	42.0	60.3	....
9	....	20.1	52.4	....	28	45.9	28.4	62.6	....
10	....	19.2	44.2	....	29	43.6	30.6	70.5	....
11	....	21.0	39.0	....	30	36.8	26.7	72.5	....
12	....	20.5	35.0	....	31	....	25.0	67.8	....
13	....	20.1	42.8	....					
14	....	21.0	35.6	....	Mean	[a]40.5	29.2	47.5	....
15	....	20.9	33.6	....					
16	....	21.7	34.4	....	Run-off per square mile	.795	.572	.932	....
17	....	35.3	30.8	....					
18	....	35.0	30.6	....	Run-off, depth in inches	.32	.66	1.07	....
19	....	62.5	28.5	....					

[a] June 20 to 30.

NOTE.—These data were furnished by the Chatanika Ditch Company.

MCMANUS CREEK.

McManus Creek, the left fork of Chatanika River, rises in a somewhat lower divide than Faith Creek, though Idaho and Montana forks reach well up toward the headwaters of Homestake and Charity creeks, of the Faith Creek drainage basin. The main fork and Pool and Smith creeks, which are tributary to McManus Creek near its mouth, interlock with the headwaters of Birch Creek, a tributary to the Yukon and with the West Fork of the Chena, a tributary to the Tanana. The streams in the McManus Creek basin are not so precipitous as the tributaries of Faith Creek, and the run-off per square mile is less. There are one or two possible reservoir sites in this basin, but they are not as favorable as those on Faith Creek. The drainage area above the mouth of McManus Creek is 80 square miles.

A gaging weir was established near the mouth of McManus Creek about June 22, 1907, by the Chatanika Ditch Company and regular readings were taken subsequent to that date. The following measurements were made in this drainage basin in 1907:

Discharge measurements in drainage basin of McManus Creek, 1907.

Date.	Point of measurement.	Elevation.[a]	Drainage area.	Discharge.	Run-off per square mile.
		Feet.	*Sq. miles.*	*Sec.-ft.*	*Sec.-ft.*
July 10	McManus Creek at mouth	1,375	80	15.6	0.195
Do.	....do	1,375	80	16.4	.205
July 12	McManus Creek above Smith Creek	1,400	42.8	10.2	.243
Do.	Smith Creek near mouth	,400	34	7.8	.229
Do.	McManus Creek at mouth	1,375	80	15.6	.192
July 13	McManus Creek ¾ mile above Montana Creek.	2,000	8	1.8	.162
Do.	McManus Creek below Montana Creek.	1,975	10	3.8	.380
Do.	McManus Creek 1½ miles below Idaho Creek.	1,800	26	6.5	.250
Do.	McManus Creek ½ mile above mouth	1,390	....	[b]21.4	....
July 14	McManus Creek 500 feet above Smith Creek.	1,400	42	12.4	.296
Do.	Smith Creek near mouth	1,400	34	8.7	.256
Do.	Smith Creek above Pool Creek	1,450	17	5.4	.323
Do.	Pool Creek above mouth	1,450	14	2.4	.172
Do.	McManus Creek above mouth	1,380	....	[b]19.4	....

[a] Taken from topographic map of Fairbanks quadrangle; approximate only.
[b] Measurement approximate.

Daily discharge, in second-feet, of McManus Creek at weir near mouth, 1907.

[Elevation, 1,375. Drainage area, 80 square miles.]

Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.
1		21.6	81.2	71.5	20	34.8	31.6	33.6	
2		20.1	80.8	62.8	21	34.8	26	32.2	
3		19	56.1	57.8	22	31.2	21.2	68.7	
4		18.5	51.2	57.2	23	34.8	17.8	50.3	
5		17.8	63.4		24	25	21.4	67.1	
6		16.1	60.6		25	21.7	19.1	81.2	
7		17.5	98.6		26	25	38.6	102	
8		17.8	84.3		27	24.3	29.1	92.6	
9		15.8	75.6		28	31.1	23.9	91.2	
10		15.0	77.8		29	26	21.8	114	
11		16.1	62.2		30	23.2	18.8	112	
12		15	49.8		31		16.7	94.1	
13		15.4	45.5						
14		17.8	40.0		Mean	[a] 28.5	21.4	66.4	
15		18.5	37.2						
16		19	42.4		Run-off per square mile	.356	.268	.830	
17		21.6	39.0						
18		34.7	37.4		Run-off, depth in inches	.15	.31	.96	
19		40	34.7						

[a] June 20 to 30.

NOTE.—These data were furnished by the Chatanika Ditch Company.

CHATANIKA RIVER NEAR JUNCTION OF FAITH AND MCMANUS CREEKS.

A gaging station was established July 16, 1907, on the Chatanika about 2,000 feet below the confluence of Faith and McManus creeks, and readings were taken twice each day by M. T. Kerrick, an employee of the Chatanika Ditch Company. The drainage area above this point is 132 square miles.

Discharge measurements of Chatanika River near junction of Faith and McManus creeks, 1907.

Date.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
July 16	C. C. Covert	47	58	1.58	51.9
July 26	E. B. Brigham	56	68	1.80	80.5
August 3	do	57	72	1.89	96.5
August 7	do	62	98	2.26	188

Daily gage height and discharge of Chatanika River near junction of Faith and McManus creeks, 1907.

[Elevation 1,350 feet; drainage area 132 square miles.]

Day.	July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.80	80
2			2.02	122
3			1.86	92
4			1.93	101
5			1.95	106
6			1.95	106
7			2.25	186
8			2.12	147
9			2.05	128
10			2.02	122
11			1.92	101
12			1.85	88
13			1.85	88
14			1.80	80
15			1.80	80
16			1.80	80
17	1.65	60	1.80	80
18	1.86	90	1.78	78
19	1.80	80	1.75	73
20	1.75	73	1.75	73
21	1.70	66	1.75	73
22	1.62	57	1.98	111
23	1.60	54	1.92	101
24	1.64	60	2.04	122
25	1.75	73	2.22	177
26	1.85	88	2.25	186
27	1.75	73	2.15	154
28	1.67	63	2.13	147
29	1.65	60	2.25	186
30	1.60	54	2.25	186
31	1.60	54		186
Mean		[a] 67		117
Run-off, per square mile		.508		.887
Run-off, depth in inches		.29		1.02

[a] July 17 to 31.

Note.—For September: Maximum, 1,770 second-feet; minimum, 110 second-feet; mean, 297 second-feet.

The following table gives the horsepower (80 per cent efficiency) per foot of fall that may be developed at different rates of discharge, and shows the number of days on which the discharge and the corresponding horsepower were respectively less than the amounts given in the columns for "discharge" and "horsepower."

Discharge and horsepower table for Chatanika River near junction of Faith and McManus creeks, 1907.

Discharge.	Horsepower (80 per cent efficiency) per foot fall.	Days of deficient discharge, June 16 to August 31.
Sec.-ft.		
33	3	
44	4	13
55	5	19
66	6	30
77	7	40
88	8	48
99	9	56
110	10	62
125	11.3	63
143	13	67
165	15	72
220	20	

Note.—The discharge from June 16 to 25 is estimated from float measurements; from June 25 to July 17 from discharge over weirs at the mouth of Faith and McManus creeks.

BOSTON CREEK.

Boston Creek rises in the high ridge to the north of the Chatanika, to which it is tributary, about 24 miles below Faith Creek. It is about 5 miles long and has a total fall of about 2,000 feet. The following measurement was made on this creek August 15, 1907, at an elevation of about 800 feet: Discharge, 3.9 second-feet; drainage area, 6.5 square miles; run-off, 0.60 second-foot per square mile.

MCKAY CREEK.

McKay Creek is the first stream to the west of Boston Creek, rises in the same divide, and empties into the Chatanika about 1 mile farther downstream. It is about 4 miles long and flows through a narrow, V-shaped valley. It has a drainage area of 6.7 square miles. The following measurement was made on this stream August 15, 1907, at an elevation of about 800 feet: Discharge, 3.7 second-feet; drainage area, 6.2 square miles; run-off, 0.602 second-foot per square mile.

BELLE CREEK.

Belle Creek rises in the high divide at the head of Ophir and Poker creeks and flows in a southeasterly direction to the Chatanika. The stream is about 6 miles long and flows through a deep, narrow valley. It drains an area of 11.9 square miles. A measurement was made on this stream August 15, 1907, at an elevation of about 800 feet, as follows: Discharge, 10 second-feet; drainage area, 11 square miles; run-off, 0.91 second-foot per square mile.

CROOKED CREEK.

Crooked Creek rises in the divide at the head of Poker Creek and flows in a southeasterly direction nearly parallel to Belle Creek. It drains an area of 7.2 square miles. A measurement was made near its mouth August 15, 1907, as follows: Discharge, 6.3 second-feet; drainage area, 7.2 square miles; run-off, 0.875 second-foot per square mile.

KOKOMO CREEK.

Kokomo Creek, a tributary to Chatanika River from the left about 28 miles below Faith Creek, rises in the high ridge at the head of Miller and Elliot creeks and flows in a northwesterly direction, draining an area of 33 square miles above its mouth. Daily readings were taken from a reference point in a large stump on the river bank about 1 mile above the mouth of the stream.

Discharge measurements of Kokomo Creek near mouth, 1907.

Date.	Gage height.[a]	Discharge.
	Feet.	*Sec.-ft.*
July 9	−3.00	13.9
August 14	−2.70	22.7

[a] Measured down from nail in stump.

Daily gage height and discharge of Kokomo Creek near mouth, 1907.

[Elevation, 750 feet; drainage, area 26 square miles.]

Day.	July. Gage height.	July. Discharge.	August. Gage height.	August. Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			+0.9	112
2			−1.2	68
3			2.0	43.8
4			2.2	37.9
5			2.4	31.8
6			2.4	31.8
7			2.3	34.8
8			2.4	31.8
9	−3.0	13.9	2.0	43.8
10	3.1	10.9	2.2	37.9
11	2.6	25.8	2.4	31.8
12	2.8	19.8	2.5	28.9
13	2.8	19.8	2.6	25.8
14	2.9	16.8	2.7	22.7
15	2.9	16.8		
16	2.9	16.8		
17	3.0	13.9		
18	2.8	19.8		
19	3.0	13.9		
20	3.0	13.9		
21	3.0	13.9		
22	3.1	10.9		
23	3.2	7.9		
24	3.0	13.9		
25	3.1	10.9		
26	3.0	13.9		
27	3.0	13.9		
28	3.0	13.9		
29	3.1	10.9		
30	3.2	7.9		
31	3.2	7.9		
Mean		[a] 14.2		[b] 41.6
Run-off per square mile		.546		1.60
Run-off, depth in inches		.47		.83

[a] July 9 to 31.

[b] August 1 to 14.

POKER CREEK.

Poker Creek, with its tributary, Caribou Creek, rises in the high, barren ridges about Poker Dome and opposite the headwaters of Ophir, Trail, and Washington creeks. It drains an oval-shaped area of 40.5 square miles, well covered with timber, and has steep precipitous slopes in its upper course.

The Tanana Electric Company is constructing a ditch line along the left bank of Poker Creek, following approximately the 800-foot contour. This ditch line will divert water from Poker, Little Poker, and Caribou creeks to a point on the Chatanika where about 80 feet head can be obtained. It is proposed to install a power plant at this point, to be run by water when available, and by steam at other times.

Discharge measurements in Poker Creek drainage basin, 1907.

Date.	Point of measurement.	Drainage area.	Gage height.	Discharge.	Run-off per square mile.
		Sq. miles.	*Feet.*	*Sec.-ft.*	*Sec.-ft.*
July 27	Poker Creek ½ mile above mouth	40	1.09	22.3	0.558
July 30	do	40	1.10	22.6	.565
August 9	do	40	1.32	36.6	.915
August 10	do	40	1.33	37.8	.944
Do	Caribou Creek above Little Poker Creek			10.4	
Do	Little Poker Creek near mouth			3.9	
Do	Poker Creek 1 mile above Caribou Creek			21.1	

CHATANIKA RIVER BELOW MOUTH OF POKER CREEK.

A gaging station was established on Chatanika River below Poker Creek June 23, 1907. A post gage driven firmly in the ground near the log chute of the Cleary Creek Lumber Company's mill was read twice each day by J. Fitzsimmons.

Discharge measurements of Chatanika River below mouth of Poker Creek, 1907.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-ft.*
June 22	88.5	213	1.08	246
July 4	86.8	192	.83	178
August 9	98	302	1.98	669

Daily gage height and discharge of Chatanika River below mouth of Poker Creek, 1907.

[Elevation 700 feet; drainage area 456 square miles.]

Day.	June.		July.		August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	......	....	0.9	192	2.1	752	1.45	384	2.25	860
2	......	....	.9	192	2.6	1,160	1.4	363	2.0	680
3	......	....	.9	192	2.0	680	1.3	321	1.85	590
4	......	....	.8	167	1.75	530	1.3	321	1.75	530
5	......	....	.8	167	1.75	530	1.25	300	1.70	505
6	......	....	.8	167	1.65	480	1.3	321	1.65	480
7	......	....	.8	167	1.5	405	1.3	321	1.6	455
8	......	....	.95	204	1.75	530	1.3	321	1.45	384
9	......	....	.85	180	1.9	620	1.45	384	1.25	300
10	......	....	.80	167	1.85	590	1.3	321	1.05	232
11	......	....	.90	192	1.6	455	1.35	342	1.45	384
12	......	....	.90	192	1.5	405	3.6	[a] 2,160	1.85	590
13	......	....	.95	204	1.35	342	4.45	[a] 3,160	1.80	560
14	......	....	.9	192	1.4	363	3.25	[a] 1,780	1.75	530
15	......	....	1.0	216	1.25	300	2.85	[a] 1,390	......	....
16	......	....	1.05	232	1.2	283	4.0	[a] 2,620	......	....
17	......	....	1.10	250	1.1	250	4.3	[a] 2,980	......	....
18	......	....	1.1	250	1.1	250	2.35	942	......	....
19	......	....	1.2	283	1.0	216	2.5	1 060	......	....
20	1.10	250	1.15	266	1.1	250	2.3	901	......	....
21	1.10	250	1.1	250	1.1	250	2.35	942	......	....
22	1.10	250	1.1	250	1.0	216	2.3	901	......	....
23	1.10	250	.95	204	1.15	266	2.25	860	......	....
24	1.05	232	.9	192	1.20	283	2.15	788	......	....
25	1.00	216	.9	192	1.35	342	2.0	680	......	....
26	.90	192	1.05	232	1.55	430	2.0	680	......	....
27	.9	192	1.1	250	1.3	321	2.0	680	......	....
28	1.0	216	1.1	250	1.4	363	2.0	680	......	....
29	1.1	250	1.1	250	1.55	430	2.15	788	......	....
30	1.0	216	1.0	216	1.7	505	2.35	942	......	....
31	......	....	.9	192	1.6	455	......	....	......	....
Mean	......	[b] 228	......	211	......	428	......	954	......	[c] 506
Second-feet per square mile	......	.500	......	.463	......	.939	......	2.09	......	1.11
Depth in inches	......	.20	......	.53	......	1.08	......	2.33	......	.68

[a] Estimated by extending rating curve.
[b] June 20 to 30.
[c] October 1 to 14.

NOTE.—The river was frozen over after October 14.

CLEARY CREEK.

Cleary Creek heads to the north of Pedro Dome in a rather low saddle which separates its waters from those of Little Eldorado Creek and which has an elevation of about 1,800 feet. It flows in a northerly direction for about 3 miles, then, by a gradual curve to the left, takes a northwesterly course to Chatanika River, to which it is tributary from the left about 2 miles below Poker Creek.

The creek has an average slope of about 90 feet to the mile through the mining section. It is considered the best producer in the camp. (See Pl. X.) The pay streak follows the creek channel closely about to claim 15 below. At that point it swings to the left bank, which it follows to the Chatanika Flats. (See Pl. XI, *A*.)

Cleary Creek has a drainage area of 10.5 square miles above its mouth. A measurement made July 4 near Cleary gave a discharge of 2.9 second-feet.

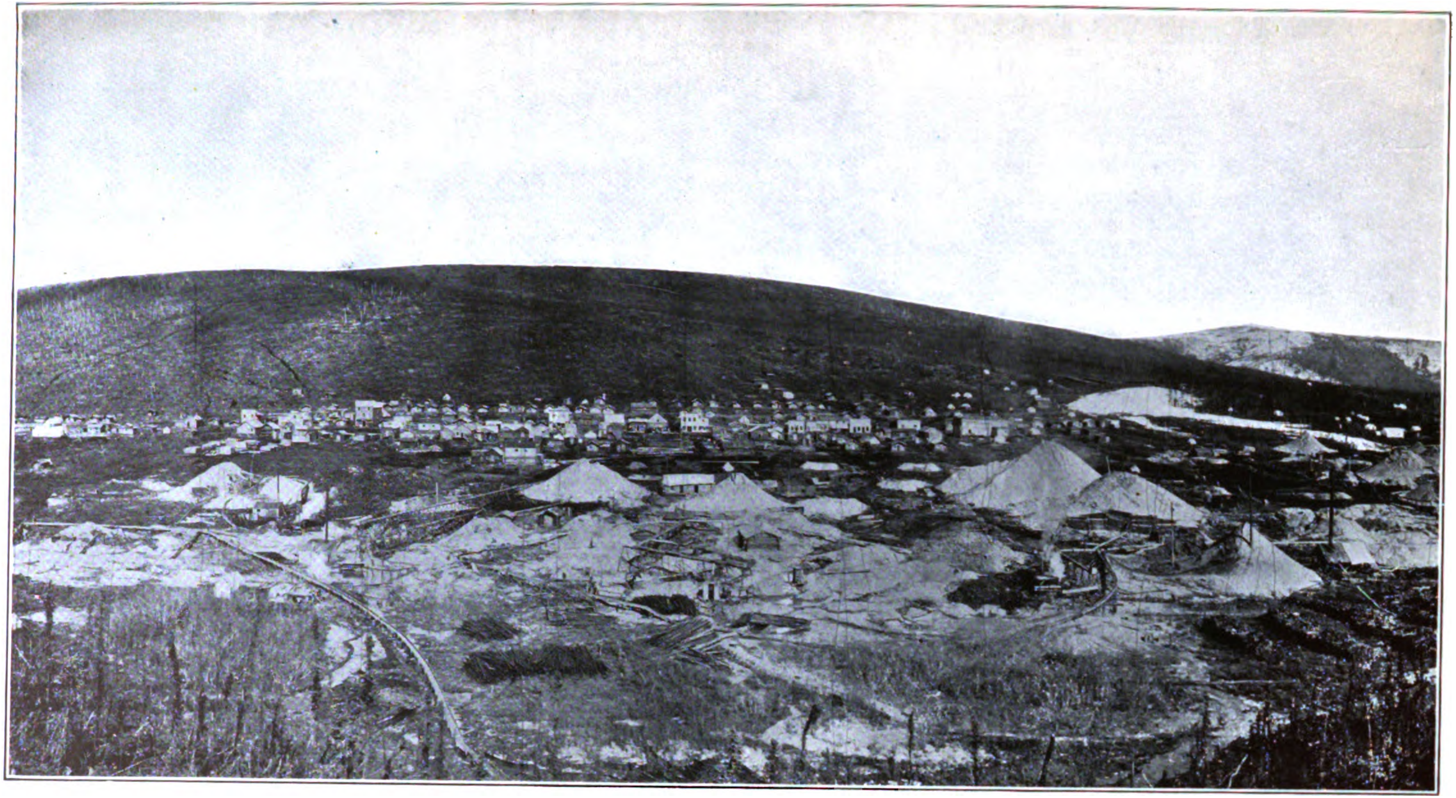
LITTLE ELDORADO CREEK.

Little Eldorado Creek rises on the western slope of Pedro Dome and drains a rather narrow valley between Dome and Vault creeks. It has a steep slope in its upper portion. The average fall of the creek through the mining section is 115 feet per mile. It is about 5 miles long and drains an area of 13.7 square miles. The creek flows in a narrow, rather deep-cut channel, well lined with willows.

The pay streak is on the right bank and is located from claim 7 above to claim 4 below. Bed rock ranges from 90 to 122 feet below the surface, with 10 to 80 feet of gravel. The following measurement was made June 26, 1907: Discharge, 0.45 second-foot, elevation, 930 feet; drainage area, 4 square miles; run-off, 0.112 second-foot per square mile.

DOME CREEK.

Dome Creek rises in the Chatanika divide, opposite Steamboat and Flume creeks, and flows northward into Chatanika River. It is about 5 miles long and drains an area of 13.9 square miles. The creek has an average grade through the mining section of about 70 feet to the mile and good values are found in its upper and lower courses. Discovery claim is located on the right bank near the town of Dome. The creek is being worked on several claims from 7 above to 20 below. The pay streak is on the right bank for practically its entire length. Bed rock ranges from 40 feet below the surface in the upper portion to more than 200 feet below in the Chatanika Flats, near the mouth. Very little water flows in the main channel during the low-water period, a large part of the flow being diverted by numer-



MINING OPERATIONS ON CLEARY CREEK.

ous small ditches. A measurement, made June 27, 1907, in a ditch near claim 2 below. gave an approximate discharge of 0.84 second-foot.

GOLDSTREAM CREEK DRAINAGE BASIN.

GENERAL DESCRIPTION.

Goldstream Creek flows through a long, narrow valley between the drainage basin of Chatanika River on the right and the Little Chena and Tanana basins on the left. It has a southwesterly direction, paralleling Chatanika River, and drains the central portion of the Fairbanks mining district. The stream flows in a winding course over a sandy, shifting bed. The channel is deeply cut in the alluvial soil that forms the bottom lands. Its length is about 70 miles and it drains an area of 500 square miles. About 40 miles below its source the stream leaves the dividing ridges and for the remainder of its course flows in a zigzag channel across the soft, mucky flats northwest of Tanana River, emptying into the Chatanika from the east.

On either side of the stream is a narrow lowland having a gradual slope toward the dividing ridges. This is covered with the conventional moss, and in the lower portion of the valley, where it widens, has numerous lakes and swamps. The bottom land has been well covered with timber, but this has disappeared to make way for railroad and mining enterprises, which make the upper portion of the valley a scene of activity. The dividing ridges on either side are well timbered with spruce and birch and rise about 1,000 feet above the stream bed. About 12 miles below the source, the southern ridge has a low saddle over which the Tanana Mines Railroad from Fairbanks enters the mining district.

The upper portion of the valley is drained by Pedro and Gilmore creeks, which join to form Goldstream Creek near Gilmore, about 12 miles north of Fairbanks.

Pedro Creek, the right fork of Goldstream Creek, is about 6 miles long and has a fall of 100 to 200 feet to the mile in its upper course. About 3 miles from its source Twin Creek, a tributary from the right, enters. Here, in 1902, gold was first found in the Fairbanks district, by Felix Pedro. Below this point the creek has a grade of about 80 feet to the mile, which gradually grows less as it approaches Goldstream Creek. Along Pedro Creek the pay streak follows the stream channel closely and bed rock is from 10 to 30 feet below the surface.

On Goldstream Creek the pay streak is along the right bank about to claim 10 below and then swings to the left bank, which it follows about to claim 22 below. Farther than this, it has not been definitely located. The depth to bed rock ranges from 20 to 60 feet.

Gilmore Creek, the left fork of Goldstream Creek, has shown small values and very little work is in progress. The creek has a fairly good grade and drains an area of 11.8 square miles.

There are numerous small tributaries to Goldstream Creek from either side. Those from the right are Fox, Gold Run, Big Eldorado, O'Connor, and Cache creeks. Those from the left are Engineer, Butter, Spear, Nugget, Straight, and Allen creeks. Prospecting and more or less mining is done on nearly all these creeks. They average from 4 to 12 miles in length and drain small areas.

On the upper portion of Goldstream Creek and along Pedro Creek several small ditches have been built to divert the water for sluicing. The largest one is that owned by the Goldstream Ditch Company. The cost of construction was about $6,500. It is about 2 miles in length and has a fall of about 7 feet to the mile. It diverts water from claim 6 below, along the left bank of Goldstream Creek, supplying several mines at the rate of $2 per hour per sluice head, which ranges from 60 to 80 inches of water. A measurement made June 28, 1907, in the lower end of a flume near the intake to this ditch gave a discharge of 10.8 second-feet.

GOLDSTREAM CREEK AT CLAIM 6 BELOW.

On account of the unfavorable condition of the channel of Goldstream Creek and the numerous small ditches that divert the flow, it was impossible to secure a good location for a gaging station. However, a gage was established near the lower line of claim 6 below, a short distance above the intake to the Goldstream ditch, June 20, 1907, and a reading was taken twice each day by John L. Meder. The water diverted by a small ditch a short distance above the gaging station is not considered in the table of estimates. Several measurements made in this ditch gave an average discharge of 1.5 second-feet.

Discharge measurements of Goldstream Creek at claim 6 below, 1907.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-feet.*
June 21	11.3	8.1	1.00	10.8
June 28	12.4	10.3	1.31	21.1

A. LOWER CLEARY CREEK.

B. GAGING STATION ON FISH CREEK.

definitely located. T
feet.

Gilmore Creek, the l
values and very little
good grade and drains

There are numerous
either side. Those fro
O'Connor, and Cache c
Butter, Spear, Nugget,
and more or less minin
average from 4 to 12 mil

On the upper portion o
several small ditches have
The largest one is that o
The cost of construction
length and has a fall of a
from claim 6 below, along
plying several mines at the
ranges from 60 to 80 inche
28, 1907, in the lower end
gave a discharge of 10.8 sec

GOLDSTREAM C

On account of the unfavor
stream Creek and the numer
it was impossible to secure
However, a gage was establishe
a short distance above the int
1907, and a reading was taken
The water diverted by a small d
station is not considered in the
ments made in this ditch gave an

Discharge measurements of Gold

Date.
June 21
June 28

Daily gage height and discharge of Goldstream Creek at claim 6 below, 1907.

[Elevation, 870 feet; drainage area, 28.6 square miles.]

Day.	June.		July.		August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.3	20.7	1.55	30.2	1.25	18.9	1.3	20.7
2			1.05	12.3	1.6	32.2	1.20	17.1	1.3	20.7
3			1.0	10.8	1.3	20.7	1.20	17.1	1.4	24.4
4			.95	9.3	1.15	15.4	1.25	18.9	1.3	20.7
5			.8	4.9	1.1	13.8	1.30	20.7	1.3	20.7
6			.75	3.6	1.15	15.4	1.2	17.1	1.3	20.7
7			1.15	15.4	1.4	24.4	1.2	17.1	1.2	17.1
8			1.05	12.3	1.45	26.3	1.15	15.4		
9			1.0	10.8	1.35	22.5	1.2	17.1		
10			.85	6.4	1.6	32.2	1.15	15.4		
11			1.6	32.2	1.45	26.3	1.35	22.5		
12			1.55	30.2	1.15	15.4	1.7	36.6		
13			1.2	17.1	1.1	13.8	1.7	36.6		
14			1.1	13.8	1.05	12.3	1.5	28.2		
15			1.65	34.4	1.05	12.3	1.5	28.2		
16			1.5	28.2	1.1	13.8	1.8	41.		
17			1.25	18.9	1.0	10.8	1.55	30.2		
18			1.15	15.4	1.0	10.8	1.45	26.3		
19			1.05	12.3	1.0	10.8	1.3	20.7		
20	1.0	10.8	1.05	12.3	1.1	13.8	1.6	32.2		
21	1.0	10.8	1.0	10.8	1.25	18.9	1.45	26.3		
22	.95	9.3	.95	9.3	1.3	20.7	1.4	24.4		
23	.8	4.9	.9	7.8	1.3	20.7	1.55	30.2		
24	.9	7.8	1.05	12.3	1.3	20.7	1.45	26.3		
25	.9	7.8	.95	9.3	1.25	18.9	1.4	24.4		
26	1.05	12.3	.95	9.3	1.35	22.5	1.4	24.4		
27	.85	6.4	.85	6.4	1.3	20.7	1.3	20.7		
28	1.3	20.7	.85	6.4	1.35	22.5	1.25	18.9		
29	1.55	30.2	.8	4.9	1.45	26.3	1.35	22.5		
30	1.45	26.3	.8	4.9	1.5	28.2	1.4	24.4		
31			.7	2.2	1.5	28.2				
Mean		[a]13.4		13.1		20.		24.		[b]20.7
Run-off per square mile		.469		.458		.699		.839		.724
Run-off, depth in inches		.192		.53		.81		.94		.19

[a] June 20 to 30.

[b] October 1 to 7.

NOTE.—These discharges do not include the amount diverted at claim 3 below by a small ditch, carrying from 1 to 1.5 second-feet. The creek was frozen after October 7.

FOX CREEK.

Fox Creek rises in the Chatanika divide opposite Vault Creek. It is about 3½ miles long and flows southward, through a V-shaped valley, into Goldstream Creek. The following measurement was made July 6, 1907: Discharge, 2.0 second-feet; elevation, 900 feet.

BEAVER CREEK DRAINAGE BASIN.

GENERAL DESCRIPTION

A high limestone ridge—the White Mountains—50 miles to the north of Fairbanks, is perhaps the highest portion of the divide between the Yukon and Tanana drainage basins. Beaver Creek, which drains the largest part of this particular portion of the divide, has its source far back in the deep canyons of the southern slope. There are two branches of Beaver Creek in its upper drainage basin that join at about latitude 65° 25′ north, and longitude 147° west. These two branches drain the highest portion of the mountains. The southern branch rises in a high ridge opposite the tributaries of Preacher Creek. It has a steep and tortuous course, flowing over a rocky bed and through a deep valley. The northern or main branch of Beaver Creek drains to the south the central portion of the mountain ridge. The gorgelike valley of the upper portion of this branch runs in an east-west direction and forms with the main valley a letter T. The course of the northern branch is tortuous and the bed is rough and gravelly. In the valley at the junction of these two branches some timber is found, and there are also small patches of meadow land. From the junction the main stream takes a westerly course for about 25 miles, then makes an abrupt bend to the right and flows in a northeasterly direction, draining the northern slope of the White Mountains. Its course above the "big bend" is through a rather broad, parklike valley, over a wide gravelly bed, in a series of riffles and pools. This portion of the stream, with its tributaries, drains the southern slope of the White Mountains. In many places the stream has several channels, forming numerous islands which are usually covered with a heavy growth of timber.

Bear and Bryan creeks are the important tributaries from the right. High, barren limestone ridges separate these creeks and form deep, narrow, gorgelike valleys, through which the streams flow over precipitous, narrow beds.

There is but little timber on the slopes of the mountains except in the lower course of the stream, and here the average size is smaller than that of the timber in the Chatanika and Little Chena basins.

The southern tributaries of Beaver Creek above the big bend are Nome, Ophir, Trail, and Wickersham creeks, whose upper portions drain the dividing ridge to the north of Chatanika River. These streams have more gradual slopes than the northern tributaries, and flow through rather narrow channels cut deep into the soft, alluvial soil of which their bottom lands consist. The ridges separating these creeks are at a much lower elevation than those on the northern slope. They are covered with timber and the many small streams which drain their slopes are fed by numerous springs. The general direction of these streams, with the exception of Nome Creek, is to the northwest—a course almost opposite to that of the main creek which receives their black, tranquil waters.

The upper portion of the Beaver Creek drainage basin is oval in shape and rises to an elevation of 1,800 to 4,000 feet. A portion of the easterly divide has an altitude of 5,000 feet. About 8 miles below the "big bend" Fossil Creek enters Beaver Creek from the right through a deep, narrow canyon. It drains a long, narrow valley of rather high elevation, and rises on the northern slope of Cache Mountain, which has an elevation of over 4,000 feet and separates the Fossil Creek drainage basin from that of Bryan Creek. Fossil Creek flows in a northerly direction for 5 or 6 miles, makes a long, easy curve to the left, flows around the northern foothills, and finally takes a southwesterly course close to the high limestone ridge that separates it from Beaver Creek.

In the upper portion of the Fossil Creek basin, on the right-hand side, there is a marked case of stream piracy. A small stream reaches into the right-hand part of the basin and takes a portion of the drainage through a gorge of high elevation into Beaver Creek, about 12 miles below the mouth of Fossil Creek

Victoria Creek, a tributary from the left about 20 miles below Fossil Creek, has its source nearly opposite Cache Mountain and is separated from Beaver Creek, which it parallels for about 50 miles, by a limestone ridge ranging from 1,000 to nearly 3,000 feet above the bed of the stream.

Some distance below the mouth of Victoria Creek, Beaver Creek changes its course to the left and flows in a northwesterly direction through a less mountainous country to the Yukon.

Beaver Creek has every indication of furnishing a good water supply. Its high drainage basin makes its waters desirable for either hydraulicking or power development. Although the present location of the mining camps is at a prohibitive distance for ditch lines, future developments may make valuable any information concerning the daily flow and run-off in this drainage basin.

MEASUREMENTS.

The following miscellaneous measurements were made in Beaver Creek drainage basin:

Miscellaneous measurements in Beaver Creek drainage basin, 1907.

Date.	Stream.	Approximate elevation.	Drainage area.	Discharge.	Run-off per square mile.
		Feet.	*Sq. miles.*	*Sec.-ft.*	*Sec.-ft.*
August 27	Trail Creek	1,700	27	39.9	1.48
Do	Brigham Creek	1,500	15	16.0	1.06
August 28	Fossil Creek	1,300	....	19.2	....
August 29	Bryan Creek	1,800	48	75.3	1.57
August 30	Beaver Creek above East Branch	1,800	122	267	2.19
Do	East Branch Beaver Creek above mouth	1,800	67	124	1.85
Do	Nome Creek near mouth	1,700	120	135	1.12

COMPARATIVE RUN-OFF OF DIFFERENT AREAS.

In order to afford a comparison of the run-off of different drainage areas in 1907, the following tables have been prepared, showing the minimum daily flow, the monthly means in second-feet per square mile, and the mean weekly flow of the drainage areas investigated. These tables can be used in estimating the run-off of other streams in this section having similar areas. Considerable care should be used in making such estimates, on account of local conditions affecting the run-off.

Minimum daily flow of streams in Fairbanks district, 1907.

Point of measurement.	Elevation.	Date.	Minimum flow.	Drainage area.	Minimum run-off per square mile.	Duration of record.	
						From—	To—
	Feet.		*Sec.-ft.*	*Sq. miles.*	*Sec.-ft.*		
Little Chena River above Elliott Creek.	800	July 22-25, 29-31...	42	79	0.53	July 22	Sept. 10
Elliott Creek above Sorrels	800	July 31	2.5	13.8	.18	...do....	Do.
Sorrels Creek above mouth	800	...do	6	21	.28	...do....	Do.
Fish Creek above Fairbanks Creek.	925	July 30-31	18	39	.46	...do....	Do.
Faith Creek at mouth ...	1,400	July 10	19.2	51	.38	June 20	Sept. 4
McManus Creek at mouth.	1,400	July 10-12	15	80	.19	...do....	Do.
Chatanika River below Faith Creek.	1,350	July 31	54	132	.41	July 17	Sept. 30
Kokomo Creek near mouth.	750	July 23, 30-31	7.9	26	.30	July 9	Aug. 14
Chatanika River below Poker Creek.	700	July 4-7, 10	167	456	.36	June 20	Oct. 14

Mean run-off in second-feet per square mile at gaging stations in Fairbanks district, 1907.

Stream.	Elevation.	Drainage area.	June 20-30.	July 1-31.	July 22-31.	Aug. 1-31.	Sept. 1-31.	Sept. 1-10.	Oct.
	Feet.	*Sq. miles.*							
Little Chena	800	79	....	....	0.62	1.08	....	1.09	....
Elliott	800	13.8	....	....	.43	.80	....	.72	....
Sorrels	800	21	....	....	.50	.87	....	.76	....
Fish Creek	925	39	....	....	.58	.94	....	.68	....
Faith Creek	1,400	51	0.80	0.57	....	.93	....	....	....
McManus	1,400	80	.36	.27	....	.83	....	....	....
Chatanika River below Faith Creek	1,350	132	....	....	[a] .51	.89	2.18	....	....
Chatanika River below Poker Creek	700	456	.50	.46	....	.94	2.09	....	[b] 1.11
Goldstream Creek	870	28.6	.47	.46	....	.70	.84	....	[c] .72

[a] July 17-31.

[b] October 1-10.

[c] October 1-7.

Mean weekly water supply, in second-feet, from Little Chena and Chatanika River basins, 1907.

Date.	Available for use by diversion at elevation 1,350 feet.	Available for use by pumping at elevation 700 feet.	Available for use by diversion at elevation 800 to 925 feet.				
	Chatanika River near Faith Creek.	Chatanika River below mouth of Poker Creek.	Little Chena River above Elliott Creek.	Elliott Creek above Sorrels Creek.	Sorrels Creek above mouth.	Fish Creek above Fairbanks.	Total in Little Chena drainage basin.
June 17–23	86						
June 24–30	64	216					
July 1–7	44	178					
July 8–14	36	190					
July 15–21	64	250					
July 22–28	70	224	52	7	12	24	95
July 29–August 4	80	540	80	12	18	55	165
August 5–11	128	516	110	12	24	42	188
August 12–18	82	313	73	10	16	26	125
August 19–25	104	260	56	6	10	24	96
August 26–September 1	169	413	90	11	18	26	145
September 2–8	120	324	82	9	15	26	132
September 9–15	513	1,360					
September 16–22	376	1,480					
September 23–29	216	737					
September 30–October 6		655					
October 7–13		415					
Mean	143	504	78	10	16	32	136
Maximum	513	1,480	110	12	24	55	188
Minimum	36	190	52	6	10	24	95

DEVELOPMENT OF WATER SUPPLY IN THE FAIRBANKS DISTRICT.

GENERAL CONDITIONS.

Since the discovery of gold on Pedro Creek in the Fairbanks district in 1902, considerable attention has been given to this section of Alaska, and, with nearly a $9,000,000 output in 1906, renewed interest has centered in this region.

The camp lies at the southern edge of the plateau country, almost where it breaks to the alluvial plain. At the present time a large part of the area may be spoken of as in a prospective stage of development. Little attention has been given to the development of water supply for mining purposes. The work has been carried on either by "open cuts" or by "drifting," as best suits the local conditions. The upper portions of the creeks usually favor the "open cut" method, as the bed rock ranges only from 8 to 20 feet below the surface. In the lower reaches, where the pay streak is from 50 to 250 feet underground, with 25 to 200 feet of overburden, "drifting" seems the only solution. The work being underground, where protection from severe weather is assured, this portion of the camp is active in winter as well as in summer. The pay gravel is hoisted to the surface and dumped in large piles, where it awaits the spring break-up for sluicing, when high water follows the melting of the accumulated snow. (See Pl. X, p. 122.)

The future development of this region, as of other mining districts in Alaska, depends largely on the economical development of its water resources. During July and part of August, 1907, the miners were obliged to resort to various schemes to secure sufficient water for sluicing. In some instances the water was returned for the second and third time to the sluice box by means of the steam pump, entailing extra expense both in fuel and equipment, and on a number of the creeks only about half of the mines were in operation.

DITCH LINES.

In general the relation of the mining camp to the surrounding country is not favorable for obtaining an outside water supply by gravity. The topography of the country is such that ditch lines from the larger drainage areas are not altogether practical. The camp lies in three drainage basins or valleys, separated by high dividing ridges, and, in order to supply the producing creeks in one valley with water by ditch line from another, the ditch must have a high elevation, which throws its source so far into the headwaters that there is only a small drainage area from which to draw the supply and consequently but little water.

On account of its elevation, the upper Chatanika drainage basin has received more attention concerning the water supply by ditch line to the mining camps than any other drainage area within a reasonable distance of the Fairbanks district. The supply from this stream, however, would have to be conveyed for over 100 miles through a ditch line, difficult to construct and maintain, and on account of its low head only a small number of producing creeks would be benefited.

Numerous surveys and reports have been made favoring the construction of ditch lines from this drainage basin. The first plan proposed a ditch along the left bank of the Chatanika that would deliver water to Pedro Dome at an elevation of about 1,800 feet, which would be necessary in order to supply water to Goldstream and Fairbanks creeks on the other side of the divide. The intake of such a ditch would have an elevation of about 2,000 feet, or 600 feet higher than the mouth of Faith and McManus creeks, where records of stream flow were kept during the season of 1907. The drainage area above this intake would be about 100 square miles, or about 25 per cent less than at the point where measurements were made.

During 1907 surveys were made for a proposed ditch, with an intake at the junction of Faith and McManus creeks. This ditch would deliver water to the camps at an elevation of about 1,200 feet—much too low to supply water outside of the Chatanika drainage basin. The table on page 129 shows the weekly supply that would have been available for such a ditch, and the table on page 132 shows the number of days of deficient flow without storage and the amount of storage necessary to have maintained in the ditch a flow of 75, 100, or 125 second-feet.

WATER-POWER DEVELOPMENT.

Water-power development for electric transmission in the Fairbanks district seems worthy of consideration. The table on page 118 shows the horsepower (80 per cent efficiency) that could have been developed in 1907 from the water supply of the Chatanika at the junction of Faith and McManus creeks. This table shows also the duration in days for different rates of flow. The table on page 132 shows the storage that would have been necessary for the maintenance of a daily flow of 100 second-feet, which would furnish 9.1 horsepower per foot of fall.

By constructing a ditch for 12 or 15 miles along the Chatanika, which would divert water from a point near the junction of Faith and McManus creeks, a head of about 400 feet could be obtained. A daily flow of 100 second-feet under a 400-foot head would develop 3,640 horsepower on the turbines. This could easily be transmitted to the mining camps, where, by the use of pumps, water from the Chatanika could be furnished to the producing creeks along this river. This would require less than 50 miles of distributing ditch.

A similar enterprise, mentioned in the description of the Little Chena drainage basin (p. 107), would develop sufficient power for pumping water to Fairbanks Creek.

This method of utilizing the water supply would dispense with many miles of ditch construction and would not only supply the camp with water, but also with power for running the hoist, elevating the tailings, pumping water from mines, lighting the underground work, and, in some localities, running the dredger.

STORAGE.

In this country, where for six months in the year the ground is frozen from surface to bed rock—10, 20, 30, and in many places more than 200 feet below—and the streams are closed by ice, it is perhaps more practical to use the daily flow of a stream during the open season than to attempt to conserve any excessive run-off; but continuous records may develop the fact that storage reservoirs are necessary from a commercial standpoint, notwithstanding the obvious difficulties connected with their construction and maintenance.

Computations have been made of the amounts of storage that would have been necessary to maintain discharges of 75, 100, and 125 second-feet in a ditch diverting water from Chatanika River near Faith Creek. These are given in the following table, together with the number of days of deficient flow for the different capacities:

Storage table for Chatanika River near Faith Creek, 1907.

Capacity of ditch.	Days of deficient flow.	Net storage required.	
Sec.-ft.		*Sec.-ft. for 1 day.*	*Acre-ft.*
75	40	795	1,570
100	56	2,100	4,158
125	63	3,100	6,138

This table covers the period from June 16 to September 1. During this time there were days when the discharge of the streams exceeded the capacity of the proposed ditches. This excess would have been stored in the reservoirs. The periods of deficient flow for the different ditches occurred as follows: For a capacity of 75 second-feet, from June 20 to July 17 and from August 11 to 12; for a capacity of 100 second-feet, June 18 to August 1 and August 12 to 21; for a capacity of 125 second-feet, from June 15 to August 6 and August 9 to 24.

It would have been necessary to conserve the entire amount of flow for the larger ditch previous to June 15 and 90 per cent of the storage for the 100-second-feet ditch previous to June 15. After July 30 the daily discharge of the streams would have taken care of the smaller ditch.

For the satisfactory development of water supply for either ditch lines or power purposes it is necessary to have a thorough knowledge of the flow of the streams from which the projects are to receive their supply and an understanding of the conditions affecting that flow. The success of any such project is measured largely by the information which enables the engineer to design his work in accordance with the maximum efficiency of the available water supply, and this can be determined with greater accuracy by the aid of long-continued records.

In some of the older mining camps of Alaska the results of failure to investigate the water supply and the necessity for its use before constructing a ditch line can be seen in the almost dry ditch bottoms at times of greatest demand for water and the lack of productive ground on which to use the supply when it is obtainable.

If the work set forth in the foregoing pages aids in developing the water supply in the Fairbanks district and points out to the prospector and engineer the value of first investigating the water supply and its use before building a ditch, this report, in a measure, will have served its purpose.

METEOROLOGICAL RECORDS.

By Fred F. Henshaw and C. C. Covert.

INTRODUCTION.

The United States is divided by the Appalachian and Rocky Mountain systems into three distinct geographic provinces. Rainfall records show that the precipitation is greatest on the slopes toward the coast lines, and also that it is heaviest on the higher slope. Brooks[a] shows that similar geographic divisions are present in Alaska, except that the general direction is east and west, instead of north and south as in the States, the highest range lying to the south.

Abbe[b] in his report on climatic conditions in Alaska shows clearly that the heaviest precipitation occurs on the southern coastal slope. Abbe's tables also show a marked difference between the rainfall of the coast and that of the interior. The southern portion of Alaska is characterized by its dense forests, steeply graded but small drainage areas, and heavy precipitation. In contrast to these conditions the interior has larger drainage basins, more numerous flat and broad areas, less timber, and less precipitation. In Seward Peninsula the country is characterized by barren conditions, gradual slope to one minor mountain range, and a comparatively medium rainfall, with considerable local variation.

One of the important facts brought out by the stream-gaging work in Alaska during the last two years is the direct relation existing between rainfall and run-off during the open season. This is graphically illustrated by figs. 1 and 2 in this report.

It will be seen from a study of the foregoing pages that the maximum discharge of streams usually occurs in May and June, that the minimum flow comes in July and the early part of August, and that during the latter part of August and September the discharge fluctuates, but in the aggregate increases up to the freeze-up, which occurs in October. A study of the available rainfall records shows that this distribution of flow is the direct result of climatic conditions. The winter is a season of slight precipitation. This comes in the form of snow, which accumulates up to about the middle of April, when the increasing sunshine has its effect and the general break-up begins.

---

[a] Brooks, A. H., Geography and geology of Alaska; Prof. Paper U. S. Geol. Survey No. 45, 1906, Pl. II.

[b] Abbe, Cleveland, jr., Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 189-200.

The discharge resulting from the break-up reaches its maximum in May. April, June, and July are usually the months of least precipitation. After the high water caused by the spring break-up has disappeared, there is little additional supply to the streams, owing to the frozen condition of the ground and the slight rainfall. Consequently the streams rapidly reach a point of low discharge. The rainfall records also show that during August and September there is a gradual increase in the amount of precipitation. This, together with the effect of temperature on the frozen ground, is the primary cause of the increased flow of streams at this period.

All of this information has an important bearing on the development of the country. Mention has been made elsewhere in this report of the importance of an adequate water supply in the development of placer mines, but placer mining is not the only natural resource of Alaska which affords promising fields for development. Notwithstanding the fact that in the interior the ground is frozen the greater part of the year, during the summer, when it is thawed to a slight depth, the soil produces a luxuriant growth of vegetation, particularly in the lower Tanana basin. It is possible to raise many kinds of vegetables and small fruits, as well as hay and grain, and already agricultural pursuits are being followed more or less near the large towns. With the high prices for vegetables and general produce, the truck gardener in 1906 and 1907 found this occupation almost as lucrative as mining. It is obvious that in the agricultural development of any portion of this country it is important to know the length of the growing season, the amount of precipitation, and the number of sunshiny days which may be expected.

As meteorological records play so important a part in the development of Alaska, it is gratifying to note the number of places at which they are kept. The importance of the continuity of these records can not be too strongly impressed on the observers. For a number of years the Weather Bureau and the Signal Corps of the Army have kept records which cover most of the country in a general way.

During 1906 and 1907 the Geological Survey collected a considerable amount of climatological data in the Nome and Kougarok regions of Seward Peninsula and in the Fairbanks district. The daily records for these stations and the monthly summaries for all stations since 1902 are given in the following pages. All records up to 1902 are taken from Abbe's report, to which previous reference has been made.

SEWARD PENINSULA.

When stream-gaging work was begun in Seward Peninsula in the spring of 1906, it was thought advisable to obtain records of rainfall at several points distributed so as to cover in a general way the whole of the peninsula. Four rain gages were installed, the stations selected being Nome, on the southern coast; Salmon Lake, about 40 miles inland and south of Kigluaik Mountains; claim 15, Ophir Creek, near Council in the eastern portion of the peninsula; and Deering, on the coast of Kotzebue Sound to the north. No records were obtained from Deering, and therefore all the data procured here were for the area south of the mountains, where there are no striking differences in climate. In 1907 the scope of the observations was broadened, and an attempt was made to establish a line of rainfall stations from coast to coast of the peninsula across the Kigluaik Mountains. Additional rain gages were installed at Black Point, near the head of Nome River; at the forks of Grand Central River, in the heart of the mountains; and at Shelton and Taylor, north of the mountains. No records were obtained on the northern coast. The location of these stations is shown on Pls. IV, VII, and XII, and other information in regard to them is given in the following table:

Seward Peninsula rainfall stations.

Station.	Letter on Pls. IV, VII, and XII.	Latitude.	Longitude.	Elevation.		Observer.	Date established.
				Above sea level.	Above ground.		
				Feet.	*Feet.*		
Nome..........	A	64° 30′	165° 24′	40	20	Arthur Gibson......	June 14, 1906
Salmon Lake..	B	64° 54′	164° 56′	445	2	J. P. Samuelson and M. Donworth.	June 26, 1906
Ophir..........	C	64° 59′	163° 39′	200	2	C. Arnold...........	July 1, 1906
Black Point....	D	64° 51′	165° 16′	575	2	F. F. Miller..........	June 23, 1907
Grand Central	E	64° 58′	165° 14′	690	2	Cornelus Edmunds	July 10, 1907
Shelton........	F	65° 13′	164° 48′	60	2	Lars Gunderson....	July 12, 1907
Taylor..........	G	65° 42′	164° 48′	550	2	A. E. Edgtvet......	July 18, 1907

The records for 1907 show a striking difference between the Kigluaik region and the country south of the mountains. The totals for the three months July to September at Shelton and Taylor are only 2.51 and 2.79 inches, respectively. These are less than one-half the total at Nome, about one-third that at Black Point and Salmon Lake, and only one-sixth the amount at Grand Central. This deficiency is probably due to the fact that the heaviest rains are accompanied by southerly winds which loose most of their moisture by the time they have passed the mountains. The largest percentage of rain accompanied by winds from the south was 76 per cent at Black Point; the smallest, 35 per cent at Taylor. The whole region is subject to local showers, many of which are heavy in one valley and not felt in the next. The rain from a general storm is often very unequally distributed.

The following statement gives briefly the climatic conditions existing in this area during the years 1899–1907:

1899. July, four rainy days; August, fourteen rainy days; September, fourteen rainy days; recorded at Teller.

1900. June and July, warm and dry, tundra fires common; August to end of September, rain.

1901. June to August, inclusive, cold and foggy with some rain; September and October, usually clear and cold with one or two hard rains of a few days' duration.

1902. June, dry; July, ten rainy days; August, six rainy days; September, three rainy days; recorded at Teller.

1903. Summer warm; little rain, but considerable fog.

1904. June, dry; rainy days as follows: Ten in July, ten in August, ten in September; temperature moderate.

1905. Very wet and cold the whole season.

1906. Very warm and dry; tundra fires common; maximum temperature 85°.

1907. A heavy snowfall and a late spring; rainfall not excessive, but water supply of Nome region good on account of its even distribution throughout the season.

The records of rainfall, snowfall, temperature, and other weather elements observed in Seward Peninsula are given below:

Monthly rainfall, in inches, in Seward Peninsula, 1906–7.

Station.	June.	July.	August.	September.	Total, June to August.	Total, June to September.	Total, July to September.
1906.							
Nome	Trace.	2.38	2.50	1.02	4.88	5.90	5.90
Salmon Lake	Trace.	4.92	3.33	3.26	8.25	11.51	11.51
Ophir	Trace.	3.57	1.91	(a)	5.48		
1907.							
Nome	1.31	2.08	2.68	1.41	6.07	7.48	6.17
Black point	2.62	1.94	2.85	3.26	7.41	10.67	8.05
Salmon Lake	2.31	1.79	3.65	2.26	7.75	10.01	7.70
Grand Central	(a)	3.61	7.19	5.06			15.86
Shelton	(a)	.71	1.33	.47			2.51
Taylor	(a)	.66	.96	1.17			2.79

a No record.

Daily rainfall, in inches, at stations near Nome, 1906.

Day.	July.			August.			September.	
	Nome.	Salmon Lake.	Ophir.	Nome.	Salmon Lake.	Ophir.	Nome.	Salmon Lake.
1								0.14
2						Trace.	0.04	
3		0.12						
4		.35			0.17	0.01		
5		.35		0.07	.07	.05		
6		.10	0.02		.23	.03		
7	a 0.52	.17	.23	b .41	.28			
8	.37	2.32	1.30					.06
9	.92	.31	.19	Trace.	.29	.08		
10	.14	.25				.12		
11			.85			.01		
12	.04		.01		.10			
13			.02				.12	
14		.35	.01				.01	.03
15			.02					
16			.02					
17					.10		.14	.01
18			.01				.16	[illegible]
19						.31	.23	1.06
20					.57	.31	.28	.99
21		.25	.01	.80			.04	.53
22			.01					[illegible]
23	.08		.60	.22	.50	.22		.06
24	.27	.35	.25					
25	.04		.01	.04	.01	.05		
26				.37	.78	.40		
27			.01	.30	.23	.32		
28				.14				
29				.15				
30								
31								
	2.38	4.92	3.57	2.50	3.33	1.91	1.02	[illegible]

a Total, July 1-7.

b Total, Aug. 6-7.

NOTE.—During June there was no measurable precipitation at any of the stations.

Daily rainfall and snowfall, in inches, at Nome, 1906-7.

Day.	October.	November.	December.		January.		February.		March.		April.	May.
	Rain.[a]	Rain.[a]	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.	Rain.	Rain.
1		0.20										
2		.12			0.13	1.2						
3									0.52	4.2		0.05
4					.40	3.6						.03
5	0.14								.13	1.1		.39
6					.95	6.0						.08
7			0.17	2.0					.36	3.0		.12
8												
9	.13											
10					.23	1.6			.87	7.5		
11												
12												
13					.07	.5						
14	.09				.26	5.3						.09
15					.28	4.0						.04
16												
17									.57	5.5		
18									.09	1.0		
19												
20					.32	3.0						
21												
22												
23												.04
24			.74	5.5			0.56	4.5	.75	5.7	0.03	.04
25			.24	2.8			.30	3.0	.08	.8	.07	.24
26	.23		.08	1.0			.41	3.6				
27	.34			Tr.			.04	.5				
28							.15	2.3				
29			.38	5.0								
30												
31			.30	4.5								
	.93	.32	1.91	20.8	2.64	25.2	1.46	13.9	3.37	28.8	.10	1.12

[a] Most ofthe precipitation in October and November was in the form of snow; snowfall not measured.

Daily rainfall, in inches, at stations in Seward Peninsula, 1907.

Day.	June.			July.						August.		
	Nome.	Black Point.	Salmon Lake.	Nome.	Black Point.	Salmon Lake.	Grand Central.	Shelton.	Taylor.	Nome.	Black Point.	Salmon Lake.
1												
2											0.17	
3											.02	
4											.01	
5				0.03	0.12		[a]0.12					
6	0.05	[a]0.07		.48	.35	0.54	[a].88					
7	.08	[a].11		.30	.13		[a].14					
8				.01	.14	.10	[a].24					
9												
10						.10						
11				.03	.02	.12	[b].12					
12				.02	.05		[b].16	Tr.			.09	
13				.07	.07	.10	[b].07			0.19	.04	0.40
14				.01	.04	.10	[b].13	.01		.11	.10	
15					.02		[b].11	.01		.04	.56	
16		[a].26	[c]0.46	.05	.07		[b].07	.01		.38	.50	.39
17	.08	[a].06								.07	.15	.65
18	.31	[a].56	.63	.20	.12		[b].12			.01	.02	.40
19	.06	[a].21	.32	.06	.04		[b].04			.05		
20	.21	[a].34	.36	.05	.16	.20	[b].40		.14	.22	.15	.32
21				.04	.28	.26	[b].58	.06	Tr.	.06	.06	.17
22									Tr.			
23	.02	.02		.22	.16		[b].18	.05	.29	.01		
24	.03	.08		.47		.15	[b].17	.53	.08	.11	.22	.10
25	.20	.22	.20	.04				.04		.02	.03	
26	.27	.69	.34						Tr.	1.02	.30	.65
27										.20	.22	.15
28										.07	.06	
29										.05	.05	.30
30					.17		.08		.12	.07	.10	.12
31						.12			.03			
	1.31	2.62	2.31	2.08	1.94	1.79	3.61	.71	.66	2.68	2.85	3.65

[a] Estimated by comparison of stations.

[b] July 10 to 16 total was 0.66; July 17 to 25 total was 1.49; these were distributed in proportion to rainfall at Black Point and Salmon Lake.

[c] Total June 1 to 16.

Daily rainfall, in inches, at stations in Seward Peninsula, 1907—Continued.

Day.	August - Continued.			September.						October.	November.
	Grand Central.	Shelton.	Taylor.	Nome.	Black Point.	Salmon Lake.	Grand Central.	Shelton.	Taylor.	Nome.	Nome.
1					0.10		0.05	0.01	0.03		0.04
2	0.20	0.01							.01		
3	.09	.15		0.14	.06		.04		Tr.		
4	.05	.05	0.09	.02	.16	0.34	32	.02	.33		
5							.04		Tr		.01
6				.10		.10		.01	.06		
7					.14		.07			0.02	
8				.07	.20	.10	.11	.01	.01		
9				.17	.36	.45	1.36		.27		
10				.61	1.40	.35	1.96	.20	.28		
11	.02		Tr.	.08	.33	.60	.66	.12			
12	.02		Tr.		.07	.17	.03		.01		
13	.08	.01	.03								
14	.10	.10	.07	.04	.07		.05				
15		.03	Tr.	.06	.22		08		.17		
16	.70	.09	Tr.						Tr		
17	.83	.11	.15								01
18	.40	.13	.13						Tr.		
19	.02	.05									
20		.07							Tr.		
21	.48	.03	.22	.03	.04		.03	.06			
22	.12		.01							.04	
23	.02		.01								
24	.20	.12	.07					Tr.		.05	
25	.14	.03	.02	.02	.05		a.05			.05	
26	.50	.20	.08		.06	.15	a.21				
27	.20	.07	.03	.06							
28	.07							.04			
29	1.90	.08	Tr.	.01							
30	1.03		.05								
31	.02		Tr.								
	7.19	1.33	.96	1.41	3.26	2.26	5.06	.47	1.17	.16	.06

Daily mean temperature (°F.) at Nome, 1906-7.

Day.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July	Aug.	Sept.	Oct.	Nov.
1		23.5	8.5	9.5	− 0.5	37.5	41.0	45.5	54.0	40.5	40.0	11.5
2	2.0	29.5	− 1.0	1.5	15.0	37.0	45.0	48.5	54.5	41.0	33.0	13.0
3	2.0	14.0	− 5.5	20.5	13.5	40.0	42.5	44.5	54.5	37.0	25.5	3.5
4	−2.0	25.5	− 2.0	24.0	12.5	37.5	44.0	46.0	54.0	41.5	26.5	6.0
5	−2.0	15.5	−11.5	23.0	13.0	35.5	41.0	49.0	48.0	42.0	25.5	8.5
6	5.0	25.0	−13.5	20.5	− 0.5	33.5	46.0	50.0	44.0	38.5	26.0	6.0
7	1.0	24.5	− 1.5	28.5	.0	38.5	41.0	46.5	52.0	41.0	32.5	2.5
8	− .5	11.5	−10.0	26.0	− 2.0	43.0	38.0	46.0	58.0	44.5	33.0	− 3.0
9	−5.0	− 8.0	−15.0	25.5	10.0	43.5	52.0	51.5	50.5	46.5	24.0	− 0.5
10	− .5	4.0	−13.0	29.5	3.0	39.5	50.5	56.5	50.0	47.5	22.0	[illegible]
11	−3.0	20.5	−14.0	29.0	15.0	26.0	48.0	57.5	54.5	46.5	26.0	18.5
12	6.0	25.0	−25.0	21.5	26.0	20.3	51.0	49.0	57.5	42.0	26.0	19.5
13	3.5	24.0	−20.5	7.0	33.5	22.5	57.5	49.5	59.5	39.5	19.0	[illegible]
14	3.0	18.5	−19.5	− 4.5	29.0	28.0	50.5	51.0	56.0	40.0	21.0	[illegible]
15	17.0	16.0	−27.5	− 5.0	17.5	26.0	42.0	52.0	53.5	45.5	24.0	[illegible]
16	23.0	− .5	−22.0	− 4.0	13.5	25.5	42.5	51.5	50.5	38.0	23.5	[illegible]
17	16.5	− 7.5	−18.5	15.0	5.5	30.0	43.5	49.0	48.5	39.0	26.5	[illegible]
18	8.5	−20.0	−22.5	18.5	7.0	31.0	45.0	46.5	51.0	36.0	23.0	19.5
19	3.5	− 6.0	−15.5	− 5.0	8.0	31.0	40.0	46.5	48.5	36.5	27.0	13.5
20	− .5	11.5	−22.5	− 9.0	18.5	32.0	42.0	49.5	54.0	35.5	20.0	9.5
21	−4.0	11.5	−18.0	−15.5	24.0	36.0	45.0	49.0	53.0	43.5	27.0	14.0
22	2.0	1.5	− 6.0	−17.0	26.0	37.5	43.5	48.5	48.5	38.0	27.0	6.5
23	−1.0	23.0	− 1.5	−13.5	33.0	43.5	52.5	54.0	42.0	36.0	25.0	2.5
24	10.0	21.5	12.5	16.0	33.0	39.0	52.5	53.0	38.5	37.5	29.0	4.5
25	20.0	23.5	25.0	10.0	35.5	36.5	49.0	51.0	40.0	39.0	34.0	− 3.0
26	18.0	14.0	24.5	− 8.0	37.5	34.0	47.0	52.0	45.5	45.5	29.5	− 4.5
27	8.5	13.5	17.5	−10.0	37.0	29.5	42.5	47.0	45.5	42.0	21.5	− 4.5
28	7.0	10.5	6.5	−14.5	34.0	34.5	41.5	46.0	44.0	45.0	19.5	1.5
29	19.0	4.5		−18.5	36.0	36.0	44.0	51.5	47.0	45.0	9.5	.5
30	20.0	.5		−19.5	36.0	40.5	45.5	56.0	45.5	42.0	7.5	− 3.5
31	25.5	.0		− 6.5		38.5		57.5	41.0		7.0	
Mean	6.8	11.9	− 7.6	5.6	19.0	34.3	45.5	50.0	49.8	41.1	24.5	9.5

Daily barometer, in inches, at Nome, 1906–7.

Day.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	......	29.97	30.64	30.04	30.12	30.10	29.92	30.00	29.84	29.83	29.40	29.93
2	30.85	29.68	30.64	29.67	30.22	30.25	29.83	30.00	29.68	29.93	29.44	29.75
3	30.89	28.95	30.58	29.46	29.77	30.18	29.75	29.85	29.74	29.90	29.45	29.74
4	31.00	29.31	30.50	29.66	29.60	29.77	29.75	29.71	29.88	29.90	29.55	29.76
5	30.78	29.97	30.24	29.38	29.70	29.75	29.87	29.71	30.04	29.95	29.76	29.63
6	30.43	29.12	30.05	30.04	29.82	30.00	29.81	29.66	30.14	29.88	29.77	29.42
7	30.40	29.89	29.96	29.69	29.93	29.87	29.85	29.94	29.95	29.77	29.67	29.78
8	30.79	30.43	30.23	30.21	29.86	29.80	29.82	30.02	30.00	30.17	29.69	30.03
9	30.43	31.08	30.22	30.26	29.85	29.78	29.82	29.76	29.97	30.29	30.04	29.87
10	30.36	30.81	30.03	29.59	30.05	29.68	29.73	29.85	29.85	29.95	29.95	29.98
11	30.33	30.60	29.90	29.87	29.93	29.70	29.75	29.79	29.86	29.95	29.92	30.32
12	29.99	30.47	29.79	30.15	29.75	29.72	29.86	30.21	29.84	30.44	30.05	29.98
13	30.03	30.40	29.49	30.65	29.75	29.83	30.00	30.18	29.72	30.32	30.15	29.66
14	30.24	30.37	29.60	30.50	29.85	29.82	29.86	30.10	29.89	30.09	30.20	29.57
15	30.12	30.20	29.79	30.35	30.03	30.16	29.88	29.80	29.98	30.11	30.16	29.40
16	29.75	30.28	30.20	30.14	30.27	30.40	29.99	29.90	29.74	30.10	30.06	29.56
17	29.73	30.51	30.18	29.14	30.48	30.51	29.93	29.94	29.68	29.97	29.89	29.30
18	29.86	30.32	30.39	29.46	30.36	30.50	29.66	29.90	29.76	29.90	29.77	29.31
19	30.10	29.98	30.37	29.96	30.00	30.37	30.12	29.91	29.66	29.78	29.35	29.48
20	30.35	29.26	30.43	29.80	30.06	30.32	29.96	29.55	29.22	29.20	29.20	29.34
21	30.40	29.97	30.27	30.13	30.42	30.12	29.82	29.67	29.32	29.15	29.27	29.35
22	30.27	29.84	29.95	30.54	30.33	30.08	29.86	29.80	29.58	29.68	29.68	29.27
23	29.57	30.56	29.92	30.10	30.17	30.00	29.64	29.83	29.77	29.94	29.74	29.45
24	29.38	30.73	29.29	29.10	29.96	29.93	29.90	29.83	29.66	29.93	29.44	29.64
25	29.16	30.78	29.07	29.74	29.91	30.00	29.83	29.90	29.79	29.49	29.44	29.68
26	29.77	30.74	29.21	30.39	29.73	30.08	30.00	29.90	29.67	29.55	29.48	29.78
27	30.24	30.72	29.58	30.44	29.95	30.10	30.28	29.87	29.81	29.42	29.76	29.60
28	30.24	30.72	30.02	30.66	30.06	30.20	30.29	29.96	29.64	29.28	29.78	29.42
29	30.04	30.61	....	30.72	30.28	30.11	30.22	30.00	29.70	29.56	29.77	29.75
30	29.87	30.48	....	30.32	30.00	29.91	30.18	29.96	29.23	29.70	30.00	29.87
31	29.84	30.62	....	30.26	....	29.80	....	29.75	29.59	....	30.15	......
Mean	30.17	30.24	30.02	30.01	30.01	30.03	29.91	29.88	29.75	29.64	29.74	29.65

Summary of meteorological observations at Nome, December, 1906, to November, 1907.

Total precipitation, rain, and melted snow	inches	18.30
Total snowfall	do	91.9
Maximum temperature	° F.	69
Minimum temperature	° F.	−32
Mean daily maximum temperature	° F.	30.7
Mean daily minimum temperature	° F.	17.7
Mean of means of maximum and minimum temperature	° F.	24.2
Mean barometer	inches	29.92
Number of clear days		152
Number of partly cloudy days		50
Number of cloudy days		163

FAIRBANKS DISTRICT.

In connection with the stream-flow investigations begun in the Fairbanks district in 1907, it was considered advisable to establish a few rainfall stations at different places in the territory covered. Four rain gages were installed at the places listed in the following table. All records are kept by voluntary observers.

Rainfall stations near Fairbanks.

Station.	Letter on Pls. IX and XII.	Latitude.	Longitude.	Elevation.		Observer.	Date established.
				Above sea level.[a]	Above ground.		
				Feet.	*Feet.*		
Summit Road House.	G	65° 02′	147° 26′	2,310	3	Mrs. Annie M. Walsh	July
Cleary	H	65° 05′	147° 26′	1,000	4	Charles Sinclair	June
Poker Creek	K	65° 08′	147° 28′	750	5	G. M. Sabean	Aug.
Faith Creek	L	65° 17′	146° 23′	1,400	4	M. T. Kerrick	July

[a] Approximate.

The records kept at these stations, together with those being obtained by the United States Weather Bureau at Fairbanks, Central, and Circle, give a general idea of the rainfall distribution from Fairbanks on the Tanana to Circle on the Yukon, 150 miles to the northwest.

Mean monthly precipitation at stations in Yukon-Tanana region, 1902-1907.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Length of record.	
														Yrs.	*Mos.*
Central	0.80	0.24	1.31	0.70	0.73	3.56	3.11	1.85	0.52	0.70	0.80	0.35	14.67	1	
Circle	1.05	.29	.52	.67	.83	.54	1.77	2.33	1.69	1.15	.30	.51	11.65	1	
Fairbanks	1.99	.58	.93	.11	.36	1.26	2.16	1.98	1.56	1.37	.92	.88	14.10	1	
Fort Egbart	1.01	.39	1.37	.18	.66	1.23	1.98	1.73	1.95	1.93	.72	.38	13.53	......	
Fort Gibbon	.54	.49	.46	.10	.50	.74	2.80	3.04	1.05	.85	.52	.50	11.59	1	
Kechumstuk	.46	.11	.12	.22	1.24	1.51	1.87	1.77	1.20	.62	.22	.21	9.55	2	
North Fork	.70	.39	.18	.40	1.66	2.33	2.13	2.04	1.52	.42	.52	.29	12.58	1	
Rampart	.90	.26	.67	.03	.42	1.04	2.04	2.66	1.60	.82	1.19	.33	11.96	1	
Dawson	1.01	.67	.46	.54	.97	.86	1.85	1.77	1.82	1.60	1.12	1.10	13.77	5	

NOTE.—Values for the different months are averages of all observations for that month. In the column headed "Year" is given the total of these averages. Amounts given for the winter months, October to March, represent melted snow, and as a rule are taken as one-tenth of the snowfall.

Purington[a] publishes a summary of the rainfall data previous to 1903 as compiled by Cleveland Abbe, jr. These tables show not only the marked variation in rainfall along the coast, but the variations between the rainfall of the coast and that of the interior.

A record for thirteen years and eleven months at Juneau shows a yearly average of 93.1 inches, and one for fifty-two months at Eagle gives an average of 11.4 inches. A similar table compiled from records obtained subsequent to 1902, at stations in the interior, gives a range from 9.55 inches at Kechumstuk to 14.67 inches at Central. This table also shows that the heaviest precipitation occurs during the period from June to September, inclusive, and that the months of April and May are usually months of least precipitation. For the source of the data in this table see pages 142 to 149, inclusive, in this report.

The following tables show the daily and monthly rainfall at stations near Fairbanks:

---

[a] Purington, C. W., Methods and costs of gravel and placer mining in Alaska: Bull. U. S. Geol. Survey No. 263, 1905, page 48.

Daily rainfall, in inches, at stations near Fairbanks, 1907.

Day.	January.	February.	March.	April.	May.	June.		July.			
	Fairbanks.					Fairbanks.	Cleary.	Fairbanks.	Summit Road House.	Cleary.	Faith Creek.
1	0.05										
2	.22		0.05								0.02
3	.16							0.04		0.09	
4	.35		.04								
5	.35	0.03				0.15					.04
6	.04					.09			0.30		
7						.11		.35	.06	.30	.14
8	.36					.07		.01		.09	
9	.75		.04		0.15						
10	.20					.15			.50	.47	.03
11		.16	.17			.05		.02	.12	.09	.14
12		.04	.40					.05	.22	.32	
13		.07	.17		.06						.03
14	(a)	.17	.05						.30		.05
15	.20	.21		0.03		.02		.01	.05	.19	.28
16	.30	.07				.18		.19	.24	.20	.11
17	.05	.03				.10			.03	.01	.01
18			.80			.02		.09	.24	.15	.35
19			.40						.13		
20			.10					.14			.13
21	.02										
22								.01			
23	.20										
24	.05							.25	.22	.27	.23
25			.20					.18	.15		
26								.05	.02	.12	.31
27							0.01			.07	
28		.08				.23	.41				
29					.13	.30	.42		.13	.06	
30					.01			.12		.12	
31											
Total.	[b]3.30	[b].86	[b]2.42	[b].03	.35	1.47	[c].84	1.51	2.71	2.55	1.87
Snowfall	33.0	8.6	24.2	.30							

Day.	August.					September.			October.		November.
	Fairbanks.	Summit Road House.	Cleary.	Poker Creek.	Faith Creek.	Fairbanks.	Cleary.	Poker Creek.	Fairbanks.	Poker Creek.	Poker Creek.
1	0.72	1.27	1.17		0.49				0.02		
2	.01	.06	.12		.19			Tr.			
3											
4			.09		.20	0.18	0.08	0.10	Tr.	Tr.	0.08
5					.03	.03	.14		Tr.	0.05	
6	.13	.27	.04	0.05	.11				.10	.30	
7		.07	.22	.24	.15		.12	.01	.20	.10	
8	.01	.42			.15	.18	.11	.02	.05		
9		.11	.46	.33	.10	.02	.22	.01	.09	.17	.10
10	.25		.08	.05	.02	.05		Tr.	.23	.30	
11						.23		.63	.50	.20	.03
12						.71	.21	.88	.25	.10	
13					.01		.80				
14									.03		
15	.09				.07	.22	.85	.70		Tr.	
16				.01	.04	.27		.10			
17		.09		.01							
18	.12		.05	.07	.01						
19									.20	.13	
20						.15	.15	.40			
21		.19		.13		.15		.13			
22	.05	.04	.10	.02	.13	.16	.52	.27			
23		.20	.11	.13		.37	.23	.15			
24	.18	.13	.09	.04	.15	.01					
25	.12	.03	.13	.15	.36						
26					.03						
27											
28		.26		.02	.09				.30	.20	
29	.13	.13	.22	.15	.54	.35		.30	.47	.15	.04
30					.13	.50	.39				
31											
Total.	1.81	3.27	2.88	1.40	3.00	3.58	3.82	3.70	[b]2.44	1.70	.25
Snowfall									24.4	24.0	3.30

[a] Drifting.

[b] Taken as 10 per cent of the snowfall.

[c] June 25 to 30.

SUMMARY OF RECORDS SINCE 1902.

All meteorological records obtained at stations in Alaska up to 1902 have been compiled by Abbe.[a] The following tables complete the record of precipitation to 1907, inclusive. The values for 1903 to 1905 for Weather Bureau stations have been taken from the annual report of the Chief of the Weather Bureau. Those for 1906 and 1907 were obtained from the original records through the courtesy of the Bureau officials. The snowfall is given only for 1906 and 1907. For these years the amount of rainfall and melted snow is given in the first line and the snowfall in the second line.

Most of the amounts given for the winter season in the previous years represent melted snow, and many of them have been taken as one-tenth of the observed snowfall. The water equivalent of snowfall varies considerably, and in general is probably somewhat less than this proportion in Alaska. In many parts of Alaska the snowfall is accompanied by wind and piles up in the form of drifts in sheltered places. This renders the accurate measurement of the quantity of snow very difficult, and many of these records can therefore be regarded as only approximate. The locations of all rainfall stations are given on Pl. XII.

Summary of records of precipitation at stations in Alaska.[b]

D. BLACK POINT.

[Latitude, 64° 51′; longitude, 165° 16′.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1907	......	......	......	......	......	2.62	1.94	2.85	3.26	......	......	......	......

1. CENTRAL.

[Latitude, 65° 33′; longitude, 145° 49′.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1906	0.56	0.06	0.05	0.47	0.86	4.91	4.82	1.85	0.52	0.70	0.80	0.35	15.95
	6.1	1.0	1.4	4.7	2.0	......	......	......	......	7.0	8.0	4.0	34.2
1907	1.04	.42	2.57	.93	.57	2.21	1.40	......	......	......	......	......	......
	10.0	4.0	24.0	8.0	1.5	......	......	......	......	......	......	......	......

H. CLEARY.

[Latitude, 65° 05′; longitude, 147° 26′.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1907	......	......	......	......	......	......	2.55	2.88	3.82	......	......	......	......

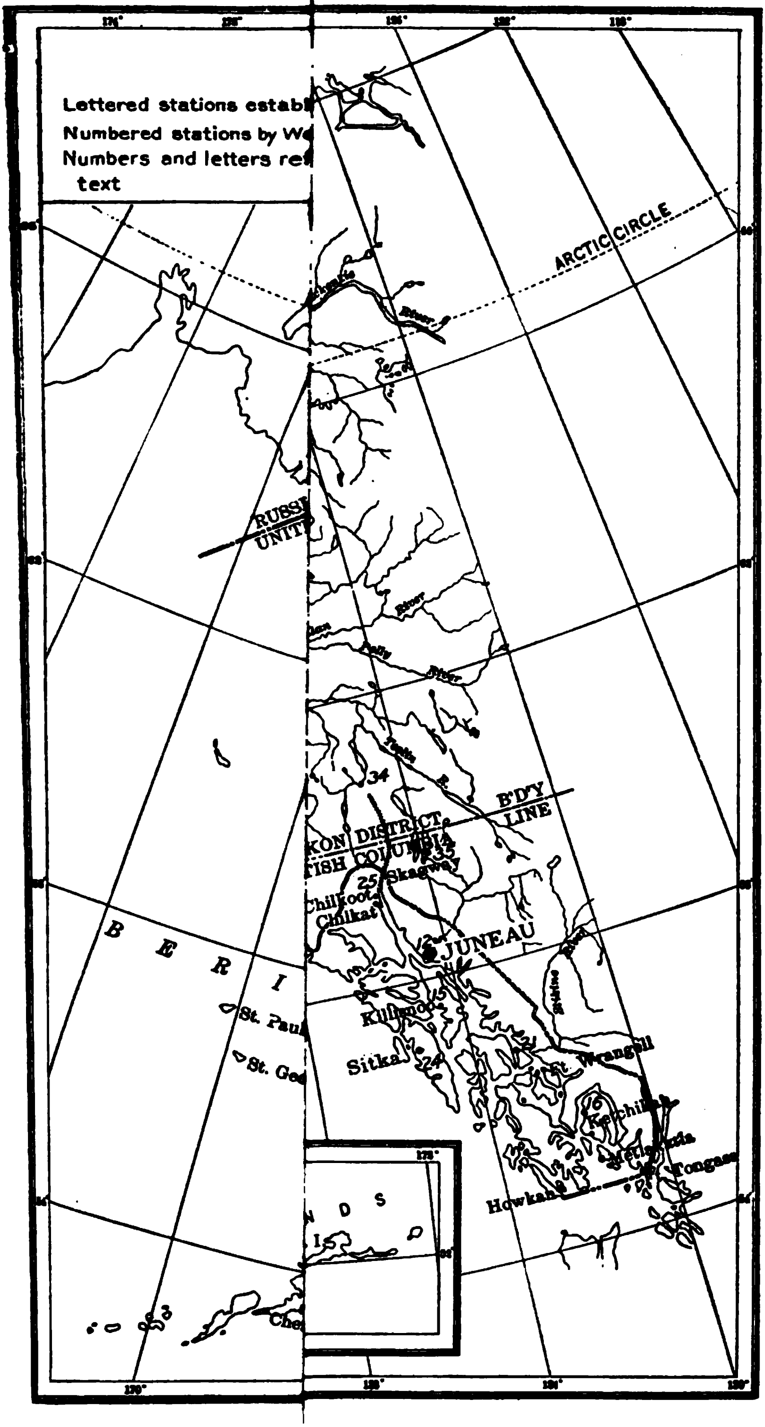
2. CHISTOCHINA.

[Latitude, 62° 36′; longitude, 144° 44′.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1904	......	......	......	......	......	......	......	0.40	2.01	......	......	0.20	......
1905	0.05	0.02	0.08	0.00	0.48	0.90	3.19	3.20	3.11	1.68	0.03	.75	13.49
1906	.26	.60	.30	Tr.	.00	.81	1.78	1.48	......	......	.50	1.80	......
	2.5	6.0	3.0	......	......	......	......	......	......	1.0	5.0	18.0	35.5
1907	2.80	.20	.80	......	Tr.	1.50	2.82	2.21	2.07	1.34	......	......	......
	28.0	2.0	8.0	......	......	......	......	......	5.0	6.0	......	......	......

---

[a] Abbe, Cleveland, jr., Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 189–200.
[b] Numbers and letters refer to Pl. XII.


Lettered stations estab
Numbered stations by W
Numbers and letters re
text
ARCTIC CIRCLE
RUSS
UNIT
B'D'Y
LINE
KON DISTRICT
TISH COLUMBIA
34
35
25
Skagway
Chilkoot
Chilkat
JUNEAU
B E R I
St. Paul
St. Geo
Killisnoo
Sitka
24
15
Ft. Wrangell
Stikine
16
Ketchikan
Metlakatla
Tongass
Howkan
N D S
I
Che

Summary of records of precipitation at stations in Alaska—Continued.

3. CIRCLE.

[Latitude, 65° 50′; longitude, 144° 4′.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1906........	......	......	......	......	......	......	......	......	......	......	......	0.75	......
	......	......	......	......	......	......	......	......	......	......	......	9.5	......
1907........	1.02	0.57	0.28	0.15	0.29	......	1.36	2.79	1.73	......	......	.63	......
	8.5	7.8	3.25	......	......	......	......	......	......	......	......	8.2	......

4. COAL HARBOR, UNGA ISLAND.

[Latitude, 55° 20′; longitude, 160° 38′.]

1903........	3.90	7.32	1.90	2.26	2.77	2.05	3.66	3.64	5.29	2.52	2.52	4.69	42.52
1904........	2.00	0.12	0.66	1.89	1.83	1.23	4.22	4.17	3.73	2.07	2.82	2.00	26.74
1905........	0.17	9.05	1.20	18.92	6.76	4.44	1.75	2.20	2.95	3.03	9.25	4.64	64.36
1906........	2.33	5.43	6.46	......	3.27	1.01	3.18	4.28	3.42	4.44	3.52	2.87	......
	5.8	1.9	4.2	Tr.	Tr.	......	......	......	......	......	7.3	2.25	......
1907........	5.65	0.20	1.43	7.99	4.59	1.88	4.71	4.90	5.84	5.83	......	......	......
	3.5	1.2	Tr.	12.75	......	......	......	......	......	Tr.	......	......	......

5. COPPER CENTER.

[Latitude, 61° 58′; longitude, 145° 20′.]

1903........	0.05	0.05	0.40	Tr.	0.60	1.38	0.99	1.16	1.34	1.71	0.20	0.75	8.63
1904........	.67	.22	Tr.	0.24	.92	1.11	1.80	2.09	.73	.48	.36	.68	9.30
1905........	.29	1.01	.20	Tr.	.48	.50	1.35	.72	1.94	.97	.94	.97	9.37
1906........	1.14	.19	.69	.36	.43	1.19	2.14	.69	.37	.84	.99	.35	9.38
	17.2	2.8	9.2	3.0	Tr.	......	......	......	......	......	8.5	6.0	46.7
1907........	......	.60	.30	......	.36	1.14	.97	.71	.25	1.35	.80	.35	......
	......	6.0	3.0	......	......	......	......	......	......	11.5	8.0	3.5	......

6. FAIRBANKS.

[Latitude, 64° 50′; longitude, 147° 44′.]

1904........	......	......	......	......	......	......	......	......	......	......	1.10	2.00	......
1905........	0.92	0.50	0.05	0.20	......	......	......	2.63	0.86	......	1.20	0.60	......
	9.1	5.0	.5	2.0	......	......	......	......	......	......	12.0	5.1	......
1906........	1.75	.37	.33	.10	0.36	1.05	2.82	1.50	.25	.30	.65	1.15	10.63
	17.5	3.7	3.3	1.0	......	......	......	......	......	0.6	6.5	11.5	45.1
1907........	3.30	.86	2.42	.03	.35	1.47	1.51	1.81	3.58	2.44	.35	.59	18.71
	33.0	8.6	24.2	.30	......	......	......	......	......	24.4	3.5	5.9	99.9

L. FAITH CREEK.

[Latitude, 65° 17′; longitude, 146° 23′.]

1907........	......	......	......	......	......	......	1.87	3.00	2.97	......	......	......	......

7. FORT EGBERT.

[Latitude, 64° 45′; longitude, 141° 10′.]

1903........	0.58	0.81	0.54	0.12	1.38	0.57	2.40	0.97	2.97	......	......	......	......
1905........	......	......	......	......	.33	1.95	1.52	2.72	3.38	2.96	0.93	0.68	......
1906........	......	.14	2.19	.00	.54	.51	2.54	1.28	.01	1.71	.51	.07	......
	......	1.0	11.0	......	......	......	......	......	......	4.6	8.5	1.0	......
1907........	1.45	.21	......	.25	.40	1.89	1.48	1.98	1.45	1.12	.40	......	......
	2.0	2.0	......	.15	.55	......	......	......	......	13.0	4.0	......	......

Summary of records of precipitation at stations in Alaska—Continued.

8. FORT GIBBON.

[Latitude, 65° 12′; longitude, 152°.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1903	0.37	0.73	1.14	0.23	0.16	0.38	1.76	......	0.48	0.22	0.33	Tr.	......
1904	.08	.55	.35	.09	.22	.33	1.95	3.80	.35	.39	.07	0.70	[illegible]
1905	.37	.47	Tr.	......	.84	1.50	4.90	3.02	......	......	1.10	.18	......
1906	.65	.20	.30	Tr.	1.00	......	......	......	......	[a] .50	.99	.27	......
	6.0	2.0	3.0	......	......	......	......	......	......	[a] 5.0	9.9	2.7	......
1907	1.26	......	.53	......	.30	......	2.58	2.31	2.32	1.22	.03	......	......
	12.6	......	5.0	......	......	......	......	......	4.0	12.0	1.5	......	......

[a] October 7 to 31.

9. FORT LISCUM.

[Latitude, 61° 27′ 30″; longitude, 146° 27′ 34″.]

1903	10.42	13.60	4.72	3.87	2.23	3.24	4.29	6.44	8.62	6.62	5.62	9.61	[illegible]
1904	6.80	.52	.10	4.50	.68	2.26	5.61	12.45	7.96	9.16	2.20	3.99	[illegible]
1905	3.63	5.73	7.17	2.96	7.02	3.83	3.49	9.85	......	6.06	10.37	7.75	......
1906	12.53	1.83	7.54	4.20	1.36	4.01	7.12	8.46	4.11	8.61	7.50	6.75	[illegible]
	97.6	13.5	103.2	31.6	.5	......	......	......	......	.5	57.5	63.5	[illegible]
1907	1.75	10.14	6.04	.82	4.05	2.83	11.25	10.61	11.98	16.77	7.94	7.13	91.31
	17.5	95.0	63.0	......	......	......	......	......	......	10.4	38.1	51.95	[illegible]

10. FORT YUKON.

[Latitude, 66° 34′; longitude, 145° 18′.]

1903	0.62	1.09	......	0.34	0.35	0.77	......	......	1.70	1.30	0.26	0.38	......
1904	.69	.93	0.80	3.08	4.60	2.40	1.67	......	......	......	......	......	......

E. GRAND CENTRAL.

[Latitude, 64° 58′; longitude, 165° 14′.]

1907	......	......	......	......	......	......	3.61	7.19	5.06	......	......	......	......

11. HOLY CROSS MISSION.

[Latitude, 62° 16′; longitude, 159° 50′.]

1906	......	0.78	1.26	0.39	0.22	1.52	1.97	3.22	2.47	0.11	0.90	1.02	......
1907	2.08	.55	4.49	......	......	2.95	3.73	5.39	3.56	.38	.51	......	......
	15.5	3.5	......	......	......	......	......	......	......	......	......	......	......

12. JUNEAU.

[Latitude, 58° 19′; longitude, 134° 28′.]

1903	11.31	7.29	3.09	3.74	6.74	1.44	2.26	5.45	6.94	......	......	......	......
1904	......	......	......	7.84	6.50	10.40	8.15	4.04	9.20	9.34	8.36	8.89	......
1905	2.83	3.08	5.90	4.96	1.58	2.96	1.93	7.85	......	12.74	15.49	10.32	......
1906	4.35	1.57	.56	3.03	......	1.34	3.58	3.21	3.68	12.30	12.27	2.17	......
	......	......	Tr.	2.0	......	......	......	......	......	......	7.0	......	......
1907	.48	8.88	2.74	3.10	3.93	......	3.40	6.88	17.03	11.19	4.58	......	......
	......	......	......	......	......	......	......	......	......	3.0	8.5	......	......

Summary of records of precipitation at stations in Alaska—Continued.

KATALLA.

[Latitude, 60° 11′; longitude, 144° 31′.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1907	......	......	......	7.70	4.85	8.29	14.95	11.41	12.34	25.62	12.44	......	....
	......	......	......	2.0	......	......	......	......	......	1.25	15.5	......	....

13. KENAI.

[Latitude, 60° 32′; longitude, 151° 19′.]

1903	0.83	2.18	0.44	0.67	0.54	1.16	2.48	3.78	2.72	0.77	0.78	0.18	16.53
1904	.46	.29	.02	.34	Tr.	.87	2.44	3.50	4.01	1.71	.48	.66	14.78
1905	.29	.92	.57	.46	.84	.84	1.06	6.26	.78	2.92	2.16	1.41	18.51
1906	.30	.10	1.24	.17	.29	.57	4.41	2.95	1.41	1.74	.39	1.16	14.73
	5.5	1.0	10.2	3.0	......	......	......	......	......	Tr.	7.8	10.0	37.5
1907	.68	.61	.67	.04	1.24	2.31	5.49	......	10.00	1.66	......	......	....
	5.0	15.5	8.8	Tr.	......	......	......	......	......	2.7	......	......	....

14. KECHUMSTUK.

[Latitude, 64° 07′; longitude, 142° 20′.]

1904	......	......	......	......	1.80	0.83	2.23	0.94	0.64	0.30	0.03	0.23	....
1905	0.90	0.10	0.05	0.40	.20	1.58	.40	1.48	2.16	1.18	.36	.20	9.01
1906	.36	.06	.06	.27	1.69	1.61	3.25	2.51	.51	.31	.29	.20	11.11
	4.0	.5	1.0	5.0	......	......	......	......	......	4.3	.5	3.0	18.3
1907	.12	.20	.27	Tr.	1.30	2.03	1.60	2.14	.49	.72	.40	......	....
	2.0	3.0	4.0	......	12.0	......	......	......	2.0	9.0	4.0	......	....

15. KILLISNOO.

[Latitude, 57° 22′; longitude, 134° 29′.]

1903	4.05	2.4	0.20	6.15	2.55	0.75	1.15	2.30	3.10	12.45	3.65	5.00	43.75
1904	4.30	1.25	1.20	1.35	1.75	3.35	4.60	2.30	7.70	8.20	9.20	8.55	53.75
1905	1.90	2.80	2.60	2.20	......	1.20	1.60	4.30	......	4.10	8.40	7.75	....
1906	6.90	2.70	.90	5.15	1.25	2.85	3.80	4.90	4.70	8.40	9.55	2.50	53.60
	31.0	1.5	......	......	......	......	......	......	......	......	4.0	10.0	46.5
1907	1.40	9.55	1.70	1.35	1.60	3.85	3.05	4.65	6.85	8.57	......	......	....
	14.0	31.5	7.0	......	......	......	......	......	......	......	......	......	....

16. LORING (FORKNAM HATCHERY.)

[Latitude, 55° 36′; longitude, 131° 37′.]

1904	......	......	2.05	7.27	15.80	9.68	7.97	1.15	20.20	26.01	31.90	20.01	....
1905	5.18	13.19	16.53	11.65	9.46	.84	5.26	12.71	14.07	17.94	28.49	25.92	161.24
1906	21.66	6.08	8.56	24.52	5.59	10.09	4.99	15.21	17.28	20.49	21.57	8.41	164.45
	19.5	......	......	4.2	......	......	......	......	......	......	......	7.5	31.2
1907	.53	13.03	4.98	7.70	4.30	5.23	3.73	9.75	10.14	20.09	24.55	......	....
	15.0	19.2	24.2	......	......	......	......	......	......	......	1.0	......	....

17. MINE HARBOR.

[Latitude, 55° 45′; longitude, 160° 40′.]

1903	2.36	6.61	1.00	2.25	2.59	1.01	......	2.51	5.10	3.97	2.60	5.92	....
1904	3.00	.49	.29	1.42	.81	1.30	3.79	4.78	......	......	......	......	....

Summary of records of precipitation at stations in Alaska—Continued.

A. NOME.

[Latitude, 64° 30′; longitude, 165° 24′.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1906	....	....	....	....	....	Tr.	2.38	2.50	1.02	0.93	0.32	1.91 20.8	....
1907	2.64 25.2	1.46 13.9	3.37 28.8	0.10	1.12	1.31	2.08	2.68	1.41	.16	.06	....	....

18. NORTH FORK.

[Latitude, 64° 30′; longitude, 142° 10′.]

1905	......	......	......	......	......	......	......	1.91	1.86	......	0.50	0.20	......
1906	0.70 7.0	0.50 5.0	0.10 1.0	0.80 8.0	1.98	2.74	2.69	1.01	.72	0.42 3.2	.55 4.5	.38 4.5	12.59 33.2
1907	.69 15.5	.28 3.0	.27 3.0	Tr.	1.34 4.0	1.92	1.57	3.19	2.00 5.0	1.40 12.0	.20 2.0	....	....

19. NUSHAGAK.

[Latitude, 58° 56′; longitude, 158° 24′.]

1904	......	......	......	......	......	......	2.29	4.52	4.16	1.66	Tr.	0.56	......
1905	0.20	1.45	0.40	0.40	2.51	2.75	3.84	......	......	......	......	......	......

C. OPHIR CREEK (CLAIM 15).

[Latitude, 64° 59′; longitude, 163° 39′.]

1906	......	......	......	......	......	Tr.	3.57	1.91	......	......	......	......	......

20. ORCA.

[Latitude, 60° 35′; longitude, 145° 40′.]

1903	16.74	16.60	......	......	......	......	......	10.75	16.67	17.70	13.24	23.44	......
1904	11.69	......	0.72	13.55	......	......	......	......	9.12	21.76	9.66	19.05	......
1905	8.20	11.56	12.51	9.10	10.48	6.51	4.42	12.99	......	15.57	29.64	12.81	......
1906	10.63 76.0	.94	5.34 39.0	7.54 17.0	....	....	....	....	....	....	17.08 3.0	8.56 39.0	....
1907	3.26 3.0	8.48 100.0	2.15 25.0	....	....	....	....	....	....	29.15	13.16 17.0	....	....

21. PETERSBURG.

[Latitude, 56° 49′; longitude, 132° 56′.]

1904	......	......	......	......	......	......	0.20	2.33	15.33	12.89	13.89	......	......
1905	......	......	......	7.17	3.03	1.95	4.46	10.76	......	......	......	......	......

22. POINT BARROW.

[Latitude, 71° 17′; longitude, 156° 40′.]

1903	0.20	0.10	......	......	......	0.10	0.74	1.43	0.09	......	Tr.	0.05	......
1904	Tr.	.37	0.40	0.30	......	......	......	......	......	......	......	......	......

K. POKER CREEK.

[Latitude, 65° 08′; longitude, 147° 28′.]

1906	....	....	....	....	....	....	....	1.40	3.70	1.70 24.0	0.28 3.30	....	....

Summary of records of precipitation at stations in Alaska—Continued.

23. RAMPART.

[Latitude, 65° 30′; longitude, 150° 15′.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1905	......	......	......	......	......	1.33	1.99	2.19	1.70	1.20	1.43	0.33	......
1906	0.63	0.08	0.17	0.04	0.40	.15	1.86	2.40	.59	.61	.95	.33	8.21
	7.2	2.0	1.8	.5	......	......	......	......	......	......	10.2	3.5	25.2
1907	1.17	.44	1.17	.02	.44	1.64	2.29	3.38	2.52	.65	.55	......	......
	12.0	4.5	12.8	.25	......	......	......	......	......	......	6.3	......	......

B. SALMON LAKE.

[Latitude, 64° 54′; longitude, 164° 56′.]

1906	......	......	......	......	......	Tr.	4.92	3.33	3.26	0.81	1.56	......	......
	......	......	......	......	......	......	......	......	......	......	18.0	......	......
1907	......	......	......	......	......	2.31	1.79	3.65	2.26	......	......	......	......

F. SHELTON.

[Latitude, 65° 13′; longitude, 164° 48′.]

1907	......	......	......	......	......	......	0.71	1.33	0.47	......	......	......	......

24. SITKA.

[Latitude 57° 03′; longitude 135° 19′.]

1903	6.61	8.68	2.57	4.25	3.65	0.90	2.85	3.90	5.80	14.52	6.50	14.97	75.20
1904	10.36	.43	3.04	3.39	3.80	3.22	5.95	3.74	13.27	10.38	8.78	8.13	74.49
1905	3.82	4.78	4.21	7.52	2.44	2.25	2.83	7.38	8.80	7.03	11.37	11.21	73.64
1906	7.25	1.89	1.58	10.64	3.46	3.34	7.45	4.66	5.78	15.22	15.59	6.61	83.47
	8.3	......	6.0	......	......	......	......	......	......	......	......	1.0	15.3
1907	2.36	3.55	1.75	2.16	3.84	3.66	4.66	12.60	15.75	11.77	12.13	......	......
	10.0	4.2	10.5	......	......	......	......	......	......	......	.70	......	......

25. SKAGWAY.

[Latitude, 59° 28′; longitude, 135° 20′.]

1903	2.08	1.44	0.43	0.48	1.10	0.56	0.02	2.08	1.41	9.99	1.60	3.35	24.54
1904	1.44	Tr.	.33	2.31	.84	.97	1.07	.18	2.80	5.35	6.28	......	......
1905	......	1.14	1.14	1.27	1.11	.10	.16	2.14	2.67	2.17	3.25	2.21	......
1906	......	1.16	.57	3.55	.37	2.63	2.11	2.26	1.30	5.58	6.47	.33	......
	......	......	Tr.	......	......	......	......	......	......	......	......	3.0	3.0
1907	.46	4.85	.47	1.08	.92	......	......	1.98	2.47	5.87	4.23	......	......
	Tr.	Tr.	Tr.	......	......	......	......	......	......	......	10.0	......	......

26. SUMMIT.

[Latitude, 62° 55′; longitude, 143° 48′.]

1906	1.19	0.46	1.04	1.26	1.02	4.25	......	[a] 0.03	0.12	0.07	0.74	0.49	......
	11.0	5.0	12.0	13.0	5.0	......	......	......	......	......	14.0	7.0	......
1907	1.80	.10	.70	.40	.80	2.15	......	......	......	1.40	......	......	......
	18.0	2.0	7.0	......	4.0	......	......	......	......	14.0	......	......	......

[a] August 19 to 31.

G. SUMMIT ROADHOUSE.

[Latitude, 65° 02′; longitude, 147° 26′.]

1907	......	......	......	......	......	......	2.71	3.27	......	......	......	......	......

Summary of records of precipitation at stations in Alaska—Continued.

27. SUNRISE.

[Latitude, 60° 54′; longitude, 149° 35′.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1904	1.69	0.13	0.28	5.08	1.01	1.36	1.05	5.02	2.33	9.35	2.37	8.31	37.98
1905	2.12	1.93	1.64	3.41	.84	.69	1.40	4.46	1.86	4.36	9.47	8.48	40.66
1906	2.18	.29	3.63	1.17	2.35	2.46	1.84	3.70	1.54	6.67	3.87	2.30	32.00
	30.7	3.7	33.9	3.8	......	......	......	......	......	5.0	15.0	25.5	117.6
1907	2.05	1.93	......	1.41	1.30	.74	4.62	2.29	4.45	6.03	7.32	6.78	......
	7.5	29.0	......	2.0	......	......	......	......	......	14.2	31.4	19.7	......

28. TANANA CROSSING.

[Latitude, 63° 24′; longitude, 143° 24′.]

1904	......	......	......	......	0.76	......	0.78	0.89	1.06	0.15	0.10	0.90	......
1905	0.24	0.08	0.18	0.00	.14	......	.37	2.95	......	1.40	.60	......	......
1906	.30	.00	Tr.	......	......	......	......	......	......	......	......	......	......

G. TAYLOR.

[Latitude, 65° 42′; longitude, 164° 48′.]

1907	......	......	......	......	......	......	0.66	0.96	1.17	......	......	......	......

29. TEIKHELL.

[Latitude, 61° 23′; longitude, 145° 18′.]

1904	......	......	0.05	0.75	0.40	0.79	1.53	2.00	1.21	2.82	0.90	2.95	......
1905	0.98	0.49	1.31	.04	Tr.	.80	1.05	1.02	1.41	1.48	4.90	2.34	15.82
1906	2.50	.20	1.87	.58	.25	1.39	2.70	.72	.62	2.90	3.52	.36	17.61
	25.0	2.0	26.2	5.5	Tr.	......	......	......	1.5	11.0	35.8	6.2	113.2
1907	.37	1.81	.56	.07	.80	.68	8.20	2.00	1.20	......	......	......	......
	4.5	21.4	9.0	Tr.	......	......	......	......	......	......	......	......	......

30. TYONEK.

[Latitude, 61° 03′; longitude, 151° 10′.]

1903	1.95	3.91	0.45	1.01	0.69	1.59	2.62	5.69	2.76	1.15	0.64	0.53	22.99
1904	1.07	.26	......	......	......	......	......	......	......	......	......	......	......
1905	......	......	......	......	......	1.27	......	......	.92	3.19	3.10	1.24	......
1906	.65	.49	1.32	.77	.39	1.00	2.96	2.95	1.67	......	1.04	1.38	......
	16.0	7.0	26.0	20.0	......	......	......	......	......	......	12.5	14.0	......
1907	1.96	......	1.66	.24	......	2.86	6.39	3.05	5.76	3.48	......	......	......
	21.0	......	33.0	2.0	......	......	......	......	......	4.7	......	......	......

31. UDAKTA (DUTCH HARBOR).

[Latitude, 53° 54′; Longitude, 166° 32′.]

1905	......	......	......	......	......	4.69	1.73	3.39	3.46	5.00	13.78	8.28	......
1906	3.09	9.46	12.19	3.07	6.82	1.14	3.56	3.10	2.29	7.91	5.38	5.76	63.77
	......	4.0	......	......	......	......	......	......	......	......	......	......	4.0
1907	8.76	2.49	2.93	2.97	5.36	1.27	2.11	3.25	......	7.79	......	......	......
	......	......	......	......	......	......	......	......	......	1.0	......	......	......

32. WOODY ISLAND (KODIAK ISLAND).

[Latitude, 57° 40′; longitude, 152° 25′.]

1903	4.74	8.10	0.39	4.61	4.92	7.80	4.38	4.79	7.95	6.27	3.30	8.29	65.54
1904	3.63	......	Tr.	3.68	3.35	2.26	1.36	4.89	4.63	4.84	5.20	3.24	......
1905	4.80	4.90	2.60	1.70	2.70	3.10	2.10	......	1.80	7.50	8.00	2.42	......
1906	2.50	8.60	3.50	3.80	5.10	4.70	......	1.50	6.70	5.10	3.20	......	......
	13.0	......	7.0	......	......	......	......	......	......	Tr.	3.5	......	......
1907	1.00	4.00	Tr.	.61	6.30	5.20	3.50	3.70	9.00	8.70	3.70	6.5	56.21
	2.0	26.0	Tr.	......	......	......	......	......	......	......	4.5	5.5	38.0

Summary of records of precipitation at stations in Alaska—Continued.

33. DAWSON.[a]

[Latitude, 64° 05′; longitude, 139° 28′.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1901	......	......	......	......	......	0.94	1.32	1.64	1.17	2.25	1.10	1.55	....
1902	1.73	0.20	......	0.50	0.46	.86	3.32	2.38	1.17	.92	1.10	.80	....
1903	.50	1.35	0.60	.60	.39	.50	1.11	1.47	2.41	1.25	.45	.65	13.01
1904	.82	.32	.20	.57	.96	1.71	2.14	1.66	1.01	.36	.80	1.45	12.00
1905	.23	1.30	.40	.94	.97	.25	1.93	2.51	3.52	1.84	.24	1.24	15.37
1906	1.26	.51	.22	.42	2.00	.92	1.20	1.46	1.14	.47	1.55	.93	12.08
1907	1.53	.34	.88	.23	1.06	.85	1.93	1.28	2.34	4.09	2.60	......	....

34. WHITE HORSE.[a]

[Latitude, 60° 46′; longitude, 135°.]

1905	1.72	0.00	0.18	0.10	0.15	0.20	3.30	0.92	2.10	1.50	1.20	0.30	11.67
1906	.55	.75	......	.20	.07	1.78	3.33	1.39	.50	.30	1.10	.20	....
1907	.55	.52	1.45	.75	.27	3.03	5.10	1.63	.86	.26	.90	......	....

35. ATLIN.[a]

[Latitude, 59° 45′; longitude, 133° 46′.]

1905	......	......	......	......	......	......	......	......	1.06	0.48	1.55	0.76	....
1906	1.37	0.72	Tr.	......	0.25	1.74	1.62	0.71	.78	1.45	2.55	.88	....
1907	.99	2.18	.55	0.09	.34	.32	.42	1.48	.58	.82	.51	......	....

[a] These data were furnished by the Canadian Meteorological Service.

INDEX.

A. Page.

- Abbe, Cleveland, jr., on climatic conditions in Alaska 133
  - on rainfall records in Alaska 142
- Acre-foot, definition of 9
- American River drainage basin, description of 93–94
- Arctic Creek, discharge of 90
- Arizona Creek and ditch, discharge of 90
- Arizona Creek ditch, description and discharge of 90
- Atlin, rainfall records at 149
- Aurora Creek, discharge of 64

B.

- Bear Creek, description and discharge of 112
- Bear Creek ditch, description of 100
- Beaver Creek drainage basin, description of 125–127
  - miscellaneous measurements in 127
- Belle Creek, description and discharge of 119
- Bismarck Creek, description and discharge of 93
- Black Point, Campion ditch at 35–36, 70
  - Miocene ditch at 26–27, 70
  - rainfall records at 137, 138, 142
- Blocker and Sayle ditch, description and discharge of 90
- Boston Creek, description and discharge of 118
- Boulder Creek, discharge of 92
- Brigham Creek, discharge of 127
- Brooks, A. H., on climatic provinces of Alaska 133
  - administrative work of 8
- Bryan Creek (Beaver Creek drainage) above East Branch, discharge of 127
- Bryan Creek (Serpentine River drainage), discharge of 92–93
- Budd Creek, description and discharge of 93–94
- Buffalo Creek, description and discharge 22

C.

- California Creek, discharge of 90
- Campion ditch, description of 35
  - discharge of, at Black Point 35–36, 70

Page.

- Candle ditch, description and discharge of 100
- Canyon Creek, discharge of 58
- Caribou Creek, discharge of 120
- Cascade ditch, description and discharge of 87
- Cascade intake, Taylor Creek at, discharge of 85–86
- Cedric ditch, description of 64
  - discharge of, above penstock 65, 70
  - seepage from, measurements of 65
  - water available for 65
- Central, rainfall records at 140, 142
- Charity Creek above mouth of Hope Creek, discharge 115
- Chatanika River, description and discharge of 121
  - discharge of, diagram showing 105
  - near Faith Creek, storage table for 132
  - near junction of Faith and McManus creeks, description and discharge of 117–118
    - discharge and horsepower table for 118
- Chatanika River drainage basin, description of 114–115
  - stream measurements in 115–123
- Chena Slough at Fairbanks, description and discharge of 118–109
- Chistochina, rainfall records at 142
- Circle, rainfall records at 140, 143
- Clara Creek, Miocene ditch at 27–28, 70
- Cleary, rainfall records at 140, 141, 142
- Cleary Creek, description and discharge of 122
- Climatic conditions on Seward Peninsula 134–139
- Coal Harbor, Unga Island, rainfall records at 143
- Coarse Gold Creek, description and discharge of 88–89
  - Kougarok River above, description and discharge 82–83
- Coarse Gold ditch, description of 89
- Coffee Creek, discharge of 90
- Columbia Creek, discharge of 90
- Cooperation, acknowledgment of 8–9
- Copper Center, rainfall records at 143
- Copper Creek, description and discharge of 49–50
- Copper and Jett creeks, combined discharge of 51

Page.

- Copper, Nugget, and Jett creeks, water available from, for hydraulicking placers 71, 72
- Copper Creek branch of Miocene ditch, discharge of 35
- Covert, C. C.; The Fairbanks district 101–132
  - work by 8
- Covert, C. C., and Fred F. Henshaw; "Introduction" to report 7–12
  - Meteorological records 133–149
- Crater Creek, description and discharge of 57
- Crater Lake, storage capacity of 52
- Crater Lake outlet, discharge of 44–45
- Cripple River drainage basin, description of 64
  - discharge measurements in 64–65
- Crooked Creek, description and discharge of 119
- Current meters, use of 11

D.

- Dahl Creek, water available for, at elevation of 300 to 350 feet 91
- Daisy Swift Creek, discharge of 64
- Data and methods, explanation of 9–12
- David Creek, description and discharge of, at Miocene ditch intake 22–23
  - discharge of, compared with that of Nome River at Miocene ditch intake 22–23
- David Creek ditch, description and discharge of 32–33, 70
- Dawson, rainfall records at 149
- Deep Creek, reservoir site near 115
- Dick Creek, discharge of 92–93
- Discharge measurements, methods of making 10–12
- Discovery Creek, discharge of 58
- Ditch and pipe lines, Nome region 72–76
  - Fairbanks district 130–131
  - Kougarok region 94–95
- Dolan and McFadden ditch, discharge of 90
- Dome Creek (Chatanika drainage), description and discharge of 122–123
- Dome Creek (Kruzgamepa drainage), discharge of 58, 59
- Dorothy Creek, description and discharge of 23
- Dorothy Creek siphon, Miocene ditch above 35

E.

- East Branch Beaver Creek, above mouth, discharge of 127
- Eldorado Creek, discharge of 58
- Eldorado and Flambeau River drainage basins, description of 69

Page.

- Elliott Creek, description of 110
  - discharge of, above mouth of Sorrels Creek 110
  - Little Chena River, above mouth of 109
- Equivalents, list of 10
- Eureka Creek, discharge of 90

F.

- Fairbanks, Chena Slough at 109
  - rainfall records at 140, 141, 143
- Fairbanks Creek, description and discharge of 112–113
  - Fish Creek above mouth of 111–112
- Fairbanks district, comparative run-off of different areas in 128
  - ditch lines in, surveys for 130–131
  - gaging stations in, list of 106
  - rainfall records in 139–141
  - topography and drainage of 101–103
  - water storage in 131–132
  - water supply of, conditions affecting 103–104
    - development of 129–130
    - measurements of 106–128
  - water-power possibilities in 131
- Fairhaven ditch, description of 99
- Fairhaven precinct, water supply of 99–100
- Faith Creek, description and discharge of 115
- Faith Creek Camp, rainfall records at 140, 141, 143
- Faith and McManus creeks, junction of, Chatanika River near 117–118
- Fall Creek, discharge of 60
- Fish Creek above mouth of Fairbanks Creek, description and discharge of 111–112
- Flambeau and Eldorado River drainage basins, description of 69
- Float measurements, methods of making 11
- Fort Egbert, rainfall records at 140, 143
- Fort Gibbon, rainfall records at 140, 144
- Fort Liscum, rainfall records at 144
- Fort Yukon, rainfall records at 144
- Fossil Creek, discharge of 127
- Fox Creek, description and discharge of 125

G.

- Gages, installation and use of 12
- Gaging stations, in Fairbanks district 106
  - in Kougarok region 79
  - in Nome region 18
- Glacier Creek, discharge of 60
  - Snake River above 68–69
- Gold Run, description and discharge of 48
  - lake at head of, storage capacity of 52

Page.

Gold Run, storage capacity required to maintain given discharges of ... 53

Gold Run, Grand Central River, and Thompson Creek, storage capacity required to maintain given discharges of ... 53

Gold Run, Thompson Creek, and upper Grand Central River, water available from, for hydraulicking placers ... 71, 72

Goldstream Creek at claim 6 below, description and discharge of ... 124–125

Goldstream Creek drainage basin, description of ... 123

Goose Creek, Noxapaga River above ... 92

Grand Central, rainfall records at ... 137, 138, 144

Grand Central ditch, description and discharge of ... 31–32, 70

Grand Central River, discharge of, below Nugget Creek ... 47
  discharge of, below the forks ... 46
    diagram showing ... 17

Grand Central River drainage basin, description of ... 38
  storage posibilities in ... 52–53
  stream measurements in ... 39–52

Grand Central River, North Fork of, description and discharge of ... 38–41

Grand Central River, Thompson Creek, and Gold Run, storage capacity required to maintain given discharges of ... 53

Grand Central River, upper, water available from, for hydraulicking placers ... 71, 72

Grand Central River, West Fork, description and discharge of 41–44

Grand Union Creek, discharge of ... 59

Grouse Creek branch of Miocene ditch, discharge of ... 35

H.

Harris Creek, discharge of ... 90

Henry Creek, description and discharge of ... 88

Henry Creek ditch, description of ... 88

Henry and Lincoln creeks, discharge of ... 88

Henshaw, Fred F.: The Fairhaven precinct ... 99–100
  The Kougarok region ... 77–98
  The Nome region ... 13–76
  work by ... 8

Henshaw, F. F., and C. C. Covert, "Introduction" to report ... 7–12
  Meteorological records ... 133–149

Henshaw, Fred F., and J. C. Hoyt, on water supply of Nome region ... 15

Page.

Hobson Creek, description and discharge of ... 23–24
  discharge of, at Miocene ditch intake ... 24
    below Manila Creek and diversions ... 24
  limestone springs in basin of ... 23
  Miocene ditch near ... 28–29, 70

Hobson Creek branch of Pioneer ditch, discharge of ... 70

Hobson Creek branch of Seward ditch, discharge of ... 70

Holy Cross Mission, rainfall records at ... 144

Homestake Creek, discharge of ... 90

Homestake ditch, description and discharge of ... 80, 83–84

Homestake ditch intake, Kougarok River at ... 80–81

Hope Creek, discharge of, near mouth of Zephyr Creek ... 115
  Charity Creek above mouth of ... 115

Hoyt, J. C., work by ... 8

Hoyt, J. C., and Henshaw, Fred F., on water supply of Nome region ... 15

Hydraulic mining, methods of ... 14–15

I.

Imuruk Basin drainage, streams tributary to, discharge of ... 59–60

Irene Creek, discharge of ... 64

Iron Creek, description and discharge of ... 57–58, 59

Iron Creek and tributaries, discharge of ... 58–59

Irving ditch, description and discharge of ... 83

J.

Jessie Creek, discharge of ... 64

Jett Creek, description and discharge of ... 50–51

Jett and Copper creeks, combined discharge of ... 51

Jett, Copper, and Nugget creeks, water available from, for hydraulicking placers ... 71, 72

Jett Creek ditch, description and discharge of ... 30–31, 70
  discharge of, compared with that of Nome River at Miocene intake ... 51

Josie Creek, discharge of ... 64

Juneau, rainfall records at ... 144

K.

Katalla, rainfall records at ... 145

Kechumstuk, rainfall records at ... 140, 145

Kenai, rainfall records at ... 145

Killisnoo, rainfall records at ... 145

Kokomo Creek, description and discharge of ... 119–120

Page.
Kougarok region, gaging stations in 79–94
  hydraulic development in 94
  topography and drainage of 77–78
  water supply of 77–95
    conditions affecting 78–79
Kougarok River, description and discharge of, above Coarse Gold Creek 82–83
  description and discharge of, above Taylor Creek 82
    at Homestake ditch intake 80–81
  discharge of, below Washington Creek 80
Kougarok River drainage basin, description of 79–80
  ditches in, water available for, in 1907 90–91
  mean weekly water supply of, in 1907 91
  miscellaneous discharge measurements in 90
Kruzgamepa River, discharge of, at Salmon Lake 55–57
Kruzgamepa River drainage basin, description of 54–55
  discharge measurements in 55–59

L.

Lillian Creek, discharge of 88
Limestone springs, effect of, on run-off 17
Lincoln Creek, description of 88
Lincoln and Henry creeks, discharge of 88
Little Chena River, description and discharge of, above mouth of Elliott Creek 109
Little Chena River and tributaries, discharge of, diagram showing 105
  discharge and horsepower table for 108
Little Chena River drainage basin, description of 106–108
  drainage areas of 108
Little Eldorado Creek, description and discharge of 122
Little Poker Creek, discharge of 120
Loring (Forknam hatchery), rainfall records at 145

M.

McKay Creek, description and discharge of 119
Macklin branch of Homestake ditch, discharge of 90
Macklin Creek, discharge of 90
McManus Creek, description and discharge of 116–117
McManus and Faith creeks, junction of, Chatanika River near 117–118
McMonagle ditch, discharge of 90
Meteorological records 133–149

Page.
Methods and data, explanation of 9–12
Miller Creek, description and discharge of 113
Mine Harbor, rainfall records at 145
Miner's inch, definition of 9–10
Miocene ditch, discharge of, above Dorothy Creek siphon 35
  discharge of, above and below Hobson Creek 28–29, 70
    above Snow Gulch 35
    below the Ex 30
    at Black Point 26–27, 70
    at Clara Creek 27–28, 70
    at flume 29–30, 70
    at miscellaneous points 35
  Copper Creek branch of 35
  David Creek branch of 22, 70
  Grand Central branch of 70
  Grouse Creek branch of 35
  Jett Creek branch of 70
  seepage measurements on 33–34
Miocene ditch flume, construction of, over glacier 74
Miocene ditch intake, David Creek at 22–23
  Hobson Creek at 24
  Nome River at 17, 19–21, 51
  Nugget Creek at, discharge of 50
Miocene ditch system, description of 24–26
Morning Call Creek, description and discharge of 51–52

N.

Nome, barometric records at 139
  rainfall records at 136, 137, 138, 139, 146
  snowfall at 16
  temperature records at 138
Nome Creek (Fairbanks district), discharge of 127
Nome region, climatic conditons in 16, 135
  ditches in, discharge of 70
    list of 75–76
  gaging stations in 18–69
  limestone springs in 17
  pipe lines and ditches in 72–76
  placer mining in 14–15
  rainfall in 15–16, 136, 138
  snowfall in 16
  topography and drainage of 13–14
  water-power possibilities in 76
  water supply of, conditions affecting 15–17
Nome River, discharge of, above Miocene ditch intake 19–21
  at Miocene ditch intake, discharge of, compared with that of David Creek 22
    discharge of, compared with that of Jett Creek ditch 51
    discharge of, diagram showing 17
  at Pioneer intake 21–22

Page.
Nome River, water available from, for hydraulicking placers __ 70, 72
Nome River drainage basin, description of ________________ 18–19
  ditches in ________________ 19, 75–76
  gaging stations in ______________ 19–37
North Fork, rainfall records at ___ 140, 146
North Fork of Grand Central River. *See* Grand Central River, North Fork.
North Fork [of Kougarok River], description and discharge of _ 89
North Star Creek, description and discharge of ____________ 62–63
North Star and Windy creeks and Sinuk River, water available from, for hydraulicking placers __________ 71, 72
North Star ditch above the siphon, description and discharge of ______________________ 86
North Star intake, Taylor Creek at __ 84–85
Noxapaga River above Goose Creek, discharge of ____________ 92
Noxapaga River drainage basin, description of ______________ 91–92
  miscellaneous measurements in __ 92
Nugget Creek, description and discharge of _______________ 49–50
  Grand Central River below ______ 47
Nugget, Copper, and Jett creeks, water available from, for hydraulicking placers ____ 71, 72
Nushagak, rainfall records at ______ 146

O.

Okdurok ditch, discharge of _________ 90
Ophir Creek (claim 15), rainfall records at _______________ 136, 146
Orca, rainfall records at ___________ 146

P.

Pass Creek, discharge of ___________ 59
Pedro Creek, description of ________ 123
Penny River at Sutton ditch intake, discharge _________________ 66–67
Penny River drainage basin, description of ______________ 66
Petersburg, rainfall records at ______ 146
Pilgrim River. *See* Kruzgamepa River.
Pioneer ditch, description of _______ 37
  discharge of, at Hobson Creek branch __________________ 70
  at Nome River intake ________ 21–22, 70
Pioneer ditch intake, Nome River at _ 21–22
Pipe lines and ditches _____________ 72–75, 94–95, 130–131
Placer mining, in Fairbanks region _ 102, 129
  in Kougarok region ____________ 94
  in Nome region __________ 14–15, 70–72
Point Barrow, rainfall records at ___ 146
Poker Creek, Chatanika River below mouth of ______________ 121

Page.
Poker Creek, description and discharge of ______________ 120
  rainfall record at ___ 140, 141, 146, 147
Precipitation records in Alaska, summary of ______________ 142–149
Price current meter, view of, plate showing _________________ 10
Purington, C. W., on rainfall data of Alaska _________________ 140

Q.

Quartz Creek, description and discharge of ______________ 93

R.

Rainfall records in Alaska, summary of ______________ 142–149
Rampart, rainfall records at _____ 140, 147
Reindeer Creek, discharge of _______ 92
Richards, Raymond, work by _______ 8, 15
Rock Creek, discharge of __________ 59
Run-off in inches, definition of _____ 9

S.

Salmon Lake, description of ________ 53–54
  flow into and out of, measurements of ______________ 54
  Kruzgamepa River at, discharge of ______________________ 55–57
  rainfall records at ____ 16, 136, 137, 138
  storage capacity of ____________ 53–54
Schlitz Creek, discharge of ________ 92
Second-feet per square mile, definition of _______________ 9
Second-foot, definition of __________ 9
Seepage, from Cedric ditch ________ 65
  from Miocene ditch ____________ 33–34
  from Seward ditch _____________ 36
Serpentine River drainage basin, measurements in ________ 92–93
Seward ditch, description and discharge of ______________ 36–37
  discharge of, at Nome River intake ____________________ 70
  Hobson Creek branch of ________ 70
  seepage from __________________ 36
Seward Peninsula, climatic conditions in _____________ 134–139
  relative run-off in different areas of ______________ 95–98
  water-supply investigations in _ 13–100
Shelton, rainfall records at __ 137, 138, 147
Sinuk River drainage basin, description of ____________ 60
  discharge measurements in _____ 60–64
Sinuk River, upper, discharge of ____ 60–61
Sinuk River, Windy and North Star creeks, water available from, for hydraulicking placers ________________ 71, 72
Sitka, rainfall records at __________ 147
Skagway, rainfall records at _______ 147
Slate Creek (Cripple River drainage), discharge of _______ 64

Page.
Slate Creek (Kruzgamepa River drainage), discharge of 59
Slate Creek (Sinuk River drainage), description and discharge of 63
Smith Creek, discharge of 59
Snake River above Glacier Creek, discharge of 68–69
Snake River drainage basin, description of 68
Snow Gulch, discharge of 60
Solomon River drainage basin, description of 69
miscellaneous measurements in 69
Sorrels Creek, description and discharge of 110–111
Elliott Creek above mouth of 110
Springs, stream flow derived from 17
Stewart River, description and discharge of 63
Storage possibilities, on Grand Central River headwaters 52–53
Storage reservoirs, Fairbanks district 131–132
Summit, rainfall records at 147
Summit Roadhouse, rainfall records at 140, 141, 147
Sunrise, rainfall records at 148
Sutton ditch at intake, discharge of 70
Sutton ditch intake, Penny River at 66–67

T.

Tanana Crossing, rainfall records at 148
Taylor, rainfall records at 137, 138, 148
Taylor Creek, description and discharge of, at North Star intake 84–85
discharge of, at Cascade intake 85–86
at mouth 86
Kougarok River above 82
Telkhell, rainfall records at 148
Thompson Creek, description and discharge of 49
Thompson Creek, Gold Run, and Grand Central River, storage capacity required to maintain given discharges of 53

Page.
Thompson Creek, Gold Run, and upper Grand Central River, water available from, for hydraulicking placers 71, 72
Trail Creek, discharge of 127
Turner Creek at McKay intake, discharge of 92
Tyonek, rainfall records at 148

U.

Udakta (Dutch Harbor), rainfall records at 148
Upper Oregon Creek, discharge of 64

V.

Velocity, methods of measuring 11–12

W.

Washington Creek, discharge of 90
Kougarok River below, discharge of 80
Water-power possibilities, in Fairbanks district 131
in Nome region 76
White Horse, rainfall records at 149
Willow Creek, discharge of 59
Windy Creek, description and discharge of 61–62, 90
Windy Creek ditch, discharge of 90
Windy and North Star creeks and Sinuk River, water available from, for hydraulicking placers 71, 72
Woody Island (Kodiak Island), rainfall records at 148

Y.

Yukon-Tanana region, rainfall records in 140
See also Fairbanks district.

Z.

Zephyr Creek, Hope Creek near mouth of, discharge of 115

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All of these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained, free of charge (except certain maps), on application.
2. A certain number are delivered to Senators and Representatives in Congress for distribution.
3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost.
4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

GENERAL.

The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper No. 45, 1906, 327 pp.
Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin No. 259, 1905, pp. 18–31..
The mining industry in 1905, by A. H. Brooks. In Bulletin No. 284, 1906, pp. 4–9.
The mining industry in 1906, by A. H. Brooks. In Bulletin No. 314, 1907, pp. 19–39.
Railway routes, by A. H. Brooks. In Bulletin No. 284, 1906, pp. 10–17.
Administrative report, by A. H. Brooks. In Report on progress of investigations of mineral resources of Alaska in 1904: Bulletin No. 259, 1905, pp. 13–17.
Administrative report, by A. H. Brooks. In Report on progress of investigations of mineral resources of Alaska in 1905: Bulletin No. 284, 1906, pp. 1–3.
Administrative report, by A. H. Brooks. In Report on progress of investigations of mineral resources of Alaska in 1906: Bulletin No. 314, 1907, pp. 11–18.
Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin No. 259, 1905, pp. 128–139.
The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin No. 250, 1905, 64 pp.
Markets for Alaska coal, by G. C. Martin. In Bulletin No. 284, 1906, pp. 18–29.
The Alaska coal fields, by G. C. Martin. In Bulletin No. 314, 1907, pp. 40–46.
Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Bulletin No. 263, 1905, 362 pp. (Out of stock; can be purchased from Superintendent of Documents, Washington, D. C., for 35 cents.) Abstract in Bulletin No. 259, 1905, pp. 32–46.
Geographic dictionary of Alaska, by Marcus Baker, second edition by J. C. McCormick. Bulletin No. 299, 1906, 690 pp.
Administrative report, by A. H. Brooks. In Report on progress of investigations of mineral resources of Alaska in 1907. Bulletin No. 345, pp. 5–17.
The distribution of mineral resources in Alaska, by A. H. Brooks. In Report on progress of investigations of mineral resources of Alaska in 1907. Bulletin No. 345, pp. 18–29.
The mining industry in 1907, by A. H. Brooks. In Report on progress of investigations of mineral resources of Alaska in 1907. Bulletin 345, pp. 30–53.
Prospecting and mining gold placers in Alaska, by J. P. Hutchins. In Bulletin No. 345, 1908, pp. 54–77.
Water-supply investigations in Alaska in 1906–7, by F. F. Henshaw and C. C. Covert. Water-Supply Paper No. 218, 1908, 156 pp.

Topographic maps.

Alaska, topographic map of; scale, 1:2500000. Preliminary edition by R. U. Goode. Contained in Professional Paper No. 45. Not published separately.
Map of Alaska showing distribution of mineral resources; scale, 1:5000000; by A. H. Brooks. Contained in Bulletin 345 (in pocket).
Map of Alaska; scale, 1:5000000; by Alfred H. Brooks.

In preparation.

Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Second edition.

SOUTHEASTERN ALASKA.

Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by Alfred H. Brooks. Professional Paper No. 1, 1902, 120 pp.

The Porcupine placer district, Alaska, by C. W. Wright. Bulletin No. 236, 1904, 35 pp.

The Treadwell ore deposits, by A. C. Spencer. In Bulletin No. 259, 1905, pp. 69–87.

Economic developments in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin No. 259, 1905, pp. 47–68.

The Juneau gold belt, Alaska, by A. C. Spencer, pp. 1–137, and A reconnaissance of Admiralty Island, Alaska, by C. W. Wright, pp. 138–154. Bulletin No. 287, 1906, 161 pp.

Lode mining in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin No. 284, 1906, pp. 30–53.

Nonmetallic deposits of southeastern Alaska, by C. W. Wright. In Bulletin No. 284, 1906, pp. 54–60.

The Yakutat Bay region, by R. S. Tarr. In Bulletin No. 284, 1906, pp. 61–64.

Lode mining in southeastern Alaska, by C. W. Wright. In Bulletin No. 314, 1907, pp. 47–72.

Nonmetalliferous mineral resources of southeastern Alaska, by C. W. Wright. In Bulletin No. 314, 1907, pp. 73–81.

Reconnaissance on the Pacific coast from Yakutat to Alsek River, by Eliot Blackwelder. In Bulletin No. 314, 1907, pp. 82–88.

Lode mining in southeastern Alaska in 1907, by C. W. Wright. In Bulletin No. 345, 1908, pp. 78–97.

The building stones and materials of southeastern Alaska, by C. W. Wright. In Bulletin No. 345, 1908, pp. 116–126.

Copper deposits on Kasaan Peninsula, Prince of Wales Island, by C. W. Wright and Sidney Paige. In Bulletin No. 345, 1908, pp. 98–115.

Topographic maps.

Juneau Special quadrangle; scale, 1:62500; by W. J. Peters. For sale at 5 cents each or $3 per hundred.

Topographic map of the Juneau gold belt, Alaska. Contained in Bulletin 287, Plate XXXVI, 1906. Not issued separately.

In preparation.

Physiography and glacial geology of the Yakutat Bay region, Alaska, by R. S. Tarr, with a chapter on the bed-rock geology by R. S. Tarr and B. S. Butler.

The Ketchikan and Wrangell mining districts, Alaska, by F. E. and C. W. Wright.

Berners Bay Special map; scale, 1:62500; by R. B. Oliver. (In press.)

Kasaan Peninsula Special map; scale, 1:62500; by D. C. Witherspoon and J. W. Bagley.

CONTROLLER BAY, PRINCE WILLIAM SOUND, AND COPPER RIVER REGIONS.

The mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall. Professional Paper No. 15, 1903, 71 pp. Contains general map of Prince William Sound and Copper River region; scale, 12 miles = 1 inch. (Out of stock; can be purchased from Superintendent of Documents for 30 cents.)

Bering River coal field, by G. C. Martin. In Bulletin No. 259, 1905, pp. 140–150.

Cape Yaktag placers, by G. C. Martin. In Bulletin No. 259, 1905, pp. 88–89.

Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin No. 259, 1905, pp. 128–139. Abstract from Bulletin No. 250.

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin No. 250, 1905, 64 pp.

Geology of the central Copper River region, Alaska, by W. C. Mendenhall. Professional Paper No. 41, 1905, 133 pp.

Copper and other mineral resources of Prince William Sound, by U. S. Grant. In Bulletin No. 284, 1906, pp. 78–87.

Distribution and character of the Bering River coal, by G. C. Martin. In Bulletin No. 284, 1906, pp. 65–76.

Petroleum at Controller Bay, by G. C. Martin. In Bulletin No. 314, 1907, pp. 89–103.

Geology and mineral resources of Controller Bay region, by G. C. Martin. Bulletin No. 335, 1908, 141 pp.

Notes on copper prospects of Prince William Sound, by F. H. Moffit. In Bulletin No. 345, 1908, pp. 176–178.

Mineral resources of the Kotsina and Chitina valleys, Copper River region, by F. H. Moffit and A. G. Maddren. In Bulletin No. 345, 1908, pp. 127–175.

Topographic maps.

Map of Mount Wrangell; scale, 12 miles = 1 inch. Contained in Professional Paper No. 15. Not issued separately.

Copper and upper Chistochina rivers; scale, 1:250000; by T. G. Gerdine. Contained in Professional Paper No. 41. Not issued separately.

Copper, Nabesna, and Chisana rivers, headwaters of; scale, 1:250000. D. C. Witherspoon. Contained in Professional Paper No. 41. Not issued separately.

Controller Bay region Special map; scale, 1:62500; by E. G. Hamilton. For sale at 35 cents a copy or $21.00 per hundred.

General map of Alaska coast region from Yakutat Bay to Prince William Sound; scale, 1:1200000; compiled by G. C. Martin. Contained in Bulletin No. 335.

In preparation.

The Kotsina-Chitina copper region, by F. H. Moffit.

Chitina quadrangle map; scale, 1:250000; by T. G. Gerdine and D. C. Witherspoon.

COOK INLET AND SUSITNA REGION.

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin No. 250, 1905, 64 pp.

Coal resources of southwestern Alaska, by R. W. Stone. In Bulletin No. 259, 1905, pp. 151–171.

Gold placers of Turnagain Arm, Cook Inlet, by F. H. Moffit. In Bulletin No. 259, 1905, pp. 90–99.

Mineral resources of the Kenai Peninsula; Gold fields of the Turnagain Arm region, by F. H. Moffit, pp. 1–52; Coal fields of the Kachemak Bay region, by R. W. Stone, pp. 53–73. Bulletin No. 277, 1906, 80 pp.

Preliminary statement on the Matanuska coal field, by G. C. Martin. In Bulletin No. 284, 1906, pp. 88–100.

A reconnaissance of the Matanuska coal field, Alaska, in 1905, by G. C. Martin. Bulletin No. 289, 1906, 36 pp. (Out of stock; can be purchased of Superintendent of Documents for 25 cents.)

Reconnaissance in the Matanuska and Talkeetna basins, by S. Paige and A. Knopf. In Bulletin No. 314, 1907, pp. 104–125.

Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska, by S. Paige and A. Knopf. Bulletin No. 327, 1907, 71 pp.

Topographic maps.

Kenai Peninsula, northern portion; scale, 1:250000; by E. G. Hamilton. Contained in Bulletin No. 277. Not published separately.

Reconnaissance map of Matanuska and Talkeetna region; scale, 1:250000; by T. G. Gerdine and R. H. Sargent. Contained in Bulletin No. 327. Not published separately.

Mount McKinley region; scale, 1:625000; by D. L. Reaburn. Contained in Professional Paper No. 45. Not published separately.

ALASKA PENINSULA AND ALEUTIAN ISLANDS.

Gold mine on Unalaska Island, by A. J. Collier. In Bulletin No. 259, 1905, pp. 102–103.

Gold deposits of the Shumagin Islands, by G. C. Martin. In Bulletin No. 259, 1905, pp. 100–101.

Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin No. 259, 1905, pp. 128–139. Abstract from Bulletin No. 250.

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. In Bulletin No. 250, 1905, 64 pp.

Coal resources of southwestern Alaska, by R. W. Stone. In Bulletin No. 259, 1905, pp. 151–171.

The Herendeen Bay coal field, by Sidney Paige. In Bulletin No. 284, 1906, pp. 101–108.

YUKON BASIN.

The coal resources of the Yukon, Alaska, by A. J. Collier. Bulletin No. 218, 1903, 71 pp.
The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, by L. M. Prindle. Bulletin No. 251, 1905, 89 pp.
Yukon placer fields, by L. M. Prindle. In Bulletin No. 284, 1906, pp. 109–131.
Reconnaissance from Circle to Fort Hamlin, by R. W. Stone. In Bulletin No. 284, 1906, pp. 128–131.
The Yukon-Tanana region, Alaska; description of the Circle quadrangle, by L. M. Prindle. Bulletin No. 295, 1906, 27 pp.
The Bonnifield and Kantishna regions, by L. M. Prindle. In Bulletin No. 314, 1907, pp. 205–226.
The Circle Precinct, Alaska, by Alfred H. Brooks. In Bulletin No. 314, 1907, pp. 187–204.
The Yukon-Tanana region, Alaska; description of the Fairbanks and Rampart quadrangles, by L. M. Prindle, F. L. Hess, and C. C. Covert. Bulletin No. 337, 1908, 102 pp.
Occurrence of gold in the Yukon-Tanana region, by L. M. Prindle. In Bulletin No. 345, 1908, pp. 179–186.
The Fortymile gold placer district, by L. M. Prindle. In Bulletin No. 345, 1908, pp. 187–197.
Water supply of the Fairbanks district in 1907, by C. C. Covert. In Bulletin No. 345, 1908, pp. 198–205.

Topographic maps.

Fortymile quadrangle; scale, 1:250000; by E. C. Barnard. For sale at 5 cents a copy or $3 per hundred.
Yukon-Tanana region, reconnaissance map of; scale, 1:625000; by T. G. Gerdine. Contained in Bulletin No. 251, 1905. Not published separately.
Fairbanks and Birch Creek districts, reconnaissance maps of; scale, 1:250000; by T. G. Gerdine. Contained in Bulletin No. 251, 1905. Not issued separately.
Circle quadrangle, Yukon-Tanana region; scale, 1:250000; by D. C. Witherspoon. Contained in Bulletin No. 295. Not issued separately.

In preparation.

Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper No. 218, 1908, 156 pp.
Fairbanks quadrangle map; scale, 1:250000; by D. C. Witherspoon. Contained in Bulletin No. 337, 1908.
Rampart quadrangle map; scale, 1:250000; by D. C. Witherspoon. Contained in Bulletin No. 337, 1908.
Fairbanks Special map; scale, 1:62500; by T. G. Gerdine and R. H. Sargent.

SEWARD PENINSULA.

A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900, by A. H. Brooks, G. B. Richardson, and A. J. Collier. In a special publication entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900," 1901, 180 pp.
A reconnaissance in the Norton Bay region, Alaska, in 1900, by W. C. Mendenhall. In a special publication entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900."
A reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. Professional Paper No. 2, 1902, 70 pp.
The tin deposits of the York region, Alaska, by A. J. Collier. Bulletin No. 229, 1904, 61 pp.
Recent developments of Alaskan tin deposits, by A. J. Collier. In Bulletin No. 259, 1905, pp. 120–127.
The Fairhaven gold placers of Seward Peninsula, by F. H. Moffit. Bulletin No. 247, 1905, 85 pp.
The York tin region, by F. L. Hess. In Bulletin No. 284, 1906, pp. 145–157.
Gold mining on Seward Peninsula, by F. H. Moffit. In Bulletin No. 284, 1906, pp. 132–141.
The Kougarok region, by A. H. Brooks. In Bulletin No. 314, 1907, pp. 164–181.

Water supply of Nome region, Seward Peninsula, Alaska, 1906, by J. C. Hoyt and F. F. Henshaw. Water-Supply Paper No. 196, 1907, 52 pp. (Out of stock; can be purchased of Superintendent of Documents for 15 cents.)
Water supply of the Nome region, Seward Peninsula, 1906, by J. C. Hoyt and F. F. Henshaw. In Bulletin No. 314, 1907, pp. 182-186.
The Nome region, by F. H. Moffit. In Bulletin No. 314, 1907, pp. 126-145.
Gold fields of the Solomon and Niukluk river basins, by P. S. Smith. In Bulletin No. 314, 1907, pp. 146-156.
Geology and mineral resources of Iron Creek, by P. S. Smith. In Bulletin No. 314, 1907, pp. 157-163.
The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Goodhope precincts, by A. J. Collier, F. L. Hess, P. S. Smith, and A. H. Brooks. Bulletin No. 328, 1908, 343 pp.
Investigation of the mineral deposits of Seward Peninsula, by P. S. Smith. In Bulletin No. 345, 1908, pp. 206-250.
The Seward Peninsula tin deposits, by Adolph Knopf. In Bulletin No. 345, 1908, pp. 251-267.
Mineral deposits of the Lost River and Brooks Mountain regions, Seward Peninsula, by Adolph Knopf. In Bulletin No. 345, 1908, pp. 268-271.
Water supply of the Nome and Kougarok regions, Seward Peninsula, in 1906-7, by F. F. Henshaw. In Bulletin No. 345, 1908, pp. 272-285.

Topographic maps.

The following maps are for sale at *5 cents a copy*, or $3 per hundred:
Casadepaga Quadrangle, Seward Peninsula; scale, 1:62500; by T. G. Gerdine.
Grand Central Special, Seward Peninsula; scale, 1:62500; by T. G. Gerdine.
Nome Special, Seward Peninsula; scale, 1:62500; by T. G. Gerdine.
Solomon Quadrangle, Seward Peninsula; scale, 1:62500; by T. G. Gerdine.

The following maps are for sale at *25 cents a copy*, or $15 per hundred:
Seward Peninsula, northeastern portion of, topographic reconnaissance of; scale, 1:250000; by T. G. Gerdine.
Seward Peninsula, northwestern portion of, topographic reconnaissance of; scale, 1:250000; by T. G. Gerdine.
Seward Peninsula, southern portion of, topographic reconnaissance of; scale, 1:250000; by T. G. Gerdine.

In preparation.

Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper No. 218, 1908, pp. 156.
Geology of the area represented on the Nome and Grand Central Special maps, by F. H. Moffit, F. L. Hess, and P. S. Smith.
Geology of the area represented on the Solomon and Casadepaga Special maps, by P. S. Smith.
The Seward Peninsula tin deposits, by A. Knopf.

NORTHERN ALASKA.

A reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. Professional Paper No. 10, 1902, 68 pp.
A reconnaissance in northern Alaska across the Rocky Mountains, along the Koyukuk, John, Anaktuvuk, and Colville rivers, and the Arctic coast to Cape Lisburne, in 1901, by F. C. Schrader and W. J. Peters. Professional Paper No. 20, 1904, 139 pp. (Out of stock; can be purchased of Superintendent of Documents for 40 cents.)
Coal fields of the Cape Lisburne region, by A. J. Collier. In Bulletin No. 259, 1905, pp. 172-185.
Geology and coal resources of Cape Lisburne region, Alaska, by A. J. Collier. Bulletin No. 278, 1906, 54 pp.

Topographic maps.

Fort Yukon to Kotzebue Sound, reconnaissance map of; scale, 1:1200000; by D. L. Reaburn. Contained in Professional Paper No. 10. Not published separately.
Koyukuk River to mouth of Colville River, including John River; scale, 1:1200000; by W. J. Peters. Contained in Professional Paper No. 20. (Out of stock.) Not published separately.

O

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 219

GROUND WATERS AND IRRIGATION ENTERPRISES

IN THE

FOOTHILL BELT, SOUTHERN CALIFORNIA

BY

WALTER C. MENDENHALL

WASHINGTON
GOVERNMENT PRINTING OFFICE
1908

CONTENTS.

Page.

Introduction 7

Geography 8

General geologic conditions 10

Physiography 13

- General features 13
- Origin of physical features 14
- Fault lines 16
- Relative ages of the physical features 17
- Summary 18

Rainfall 18

- Distribution and amount 18
- Dependence of water supplies on rainfall 22

Storage facilities 24

Measures for conservation of waters 25

Absorptive capacity of sands 26

Absorption estimates 28

Character and condition of subterranean reservoirs 29

The glacial hypothesis 30

Character of the rock floor of the filled areas 31

Ground-water districts 33

- Red Hills waters 34
- San Antonio underground waters 37
- Chino artesian belt 39
- San Jose Valley 42
- San Dimas district 43
  - Development 43
  - Surface conditions 43
  - Underground conditions 45
- San Gabriel Valley 47
- Pasadena Basin 50
- Fluctuations in ground-water levels 54
  - Evident effects 54
  - Measurements 56
    - Wells near Pomona 56
    - Wells near San Dimas 58
    - Wells near Vineland 60
    - Wells near Lordsburg 61
    - Wells southeast of Pomona 62
    - Wells northeast of Pomona 63
    - Wells in San Gabriel River basin 64
    - Wells in Pasadena Basin 65
    - Summary of results of water-plane measurements 66

Page.

Irrigation enterprises 67
  Introduction 67
  Etiwanda Water Company 67
  Hermosa Water Company 68
  Ioamosa Water Company 70
  Cucamonga lands and Cucamonga Water Company 71
  Old Settlers Water Company 74
  Sunset Water Company 74
  Ontario Colony and San Antonio Water Company 75
    History of rights 75
    Pipe lines and conduits 78
    Operation and maintenance 78
    Annual cost 79
  Ontario Water Company 79
  Pomona irrigation 80
    Rights 80
    Canyon Water Company of Pomona 80
    Del Monte Irrigation Company 81
    Irrigation Company of Pomona 82
    Palomares Irrigation Company 83
    Consolidated Water Company of Pomona 84
  Kingsley Tract Water Company (Limited) 85
  Mountain View Water Company 86
  Canyon Ridge Water Company 87
  Upland Water Company 87
  Orange Grove Tract Water Company 87
  Claremont Cooperative Water Company 88
  Citizens' Light and Power Company 89
  Chino Land and Water Company 89
  San Jose Valley systems 90
    Currier Tract Water Company 90
    A. T. Currier development 90
    North ditch 90
    South ditch 91
  Lordsburg Water Company 91
  Laverne Land and Water Company 92
  Laverne Irrigating Company 92
  San Dimas Irrigation Company 93
  Artesian Belt Water Company 95
  New Deal Land and Water Company 96
  Frostless Belt Water Company 96
  San Gabriel systems 97
    History of rights 97
    Azusa Irrigating Company 101
    Covina Irrigating Company 102
    Azusa Agricultural Water Company 105
  Citrus Belt Water Company 106
  Columbia Land and Water Company 106
  Western Water and Power Company 107
  Glendora-Azusa Water Company 108

Irrigation enterprises—Continued.

Page.

- Irwindale water companies 109
  - Orange Avenue Land and Water Company 109
  - Irwindale Land and Water Company 109
  - Cypress Avenue Water Company 110
- Vineland irrigation district 110
- Duarte water companies 110
  - Rights 110
  - Joint works 112
  - Duarte Mutual Irrigation and Canal Company 112
  - Beardslee Water Ditch Company 113
- Monrovia Water Company 114
- Santa Anita Water Company 114
- Baldwin systems 115
- Sierra Madre Water Company 116
- Precipice Canyon Water Company 117
- Lincoln Avenue Water Company 117
- Sunny Slope Water Company 118
- Chapea Water Company 119
- Garvey Water Company 119
- Alhambra Addition Water Company 120
- Euclid Avenue Water Company 120
- Marengo Water Company 121
- Montebello Land and Water Company 122
- North Pasadena Land and Water Company 122
- Pasadena Lake Vineyard Land and Water Company 124
  - Organization and territory 124
  - Water supply 125
  - History of water rights 125
  - Devils Gate joint works 126
  - Other works in Arroyo Seco 128
  - Independent property 128
  - Distribution 128
  - Value of properties 129
- Pasadena Land and Water Company 130
  - Organization and territory 130
  - Water supply 130
  - History of water rights 131
  - Devils Gate joint works 132
  - Independent property 132
  - Distribution 133
  - Value of properties 134
- Verdugo Canyon Water Company 135

Yield of flowing wells 137

Maps and tables 138
- Useful equivalents 139
- General statistics 139
- Well data 140
  - Wells in Cucamonga quadrangle 140
  - Wells in Pomona quadrangle 152
  - Wells in Pasadena quadrangle 160

ILLUSTRATIONS.

Page.

PLATE I. *A*, *B*, panoramic view of Arroyo Seco above Devils Gate; *C*, *D*, panoramic view of Palomares ciénaga lands and the San Gabriel Range north of the Cucamonga Plains........ 8

II. *A*, Devils Gate; *B*, submerged dam above Devils Gate........ 52

III. Map showing artesian areas and hydrographic contours in the valley of southern California........ In pocket

IV. Map showing irrigated lands, canals, pipe lines, and pumping plants in the Cucamonga quadrangle........ In pocket

V. Map showing wells, artesian areas, and water levels in the Cucamonga quadrangle........ In pocket

VI. Map showing irrigated lands, canals, pipe lines, and pumping plants in the Pomona quadrangle........ In pocket

VII. Map showing wells, artesian areas, and water levels in the Pomona quadrangle........ In pocket

VIII. Map showing irrigated lands, canals, pipe lines, and pumping plants in the Pasadena quadrangle........ In pocket

IX. Map showing wells, artesian areas, and water levels in the Pasadena quadrangle........ In pocket

FIG. 1. Section of well No. 204, Pasadena quadrangle........ 32

2. Diagrammatic section through the Red Hills........ 34

3. Section along line of the Eddy or Cucamonga tunnel........ 34

4. Section of well No. 69, Cucamonga quadrangle........ 35

5. Section of well No. 54, Cucamonga quadrangle........ 36

6. Section of well No. 73, Cucamonga quadrangle........ 37

7. Diagrammatic section from the base of the San Gabriel Range through Indian Hill, Claremont, and Chino........ 38

8. Section of Gird well No. 6, Cucamonga quadrangle........ 39

9. Section of well No. 221, Cucamonga quadrangle........ 40

10. Section of well No. 154, Cucamonga quadrangle........ 41

11. Section of well No. 247, Cucamonga quadrangle........ 45

12. Section of well No. 233, Pomona quadrangle........ 46

13. Diagrammatic section across San Dimas, Wash........ 47

14. Section of well No. 99, Pomona quadrangle........ 50

15. Section of well No. 449, Pasadena quadrangle........ 51

16. Diagrammatic section across San Gabriel Valley from Millard Canyon through Monk Hill and Oak Knoll........ 53

GROUND WATERS AND IRRIGATION ENTERPRISES IN THE FOOTHILL BELT OF SOUTHERN CALIFORNIA.

By Walter C. Mendenhall.

INTRODUCTION.

In midsummer, 1903, field work was begun on a series of studies of the conditions under which the ground waters of southern California occur. During the preceding decade the inadequacy of surface waters, the perfection of pumping machinery, the development of cheap fuel and electrical power, and the discovery of the wide distribution and accessibility of ground waters combined to make these of increasing importance in the irrigation of the intensively cultivated horticultural districts which have made this portion of the State famous. Even the largest of the systems of irrigation, which a few years ago secured their waters wholly from the mountain canyons, now usually have subsidiary pumping plants, which are depended on to keep up the supply during the summer and fall, when the streams are lowest; and in addition to plants of this character, many companies have been organized that depend entirely on pumped or artesian waters. So extensive has been this development that a conservative estimate indicates that the proportion of underground water to surface water now used during the late summer period after dry winters, when the surface supply is lowest and the pumps are busiest, is as 3 or 4 to 1.

Obviously a resource which has become so important to the continued welfare of so rich a district is worthy of careful study. Such a study is now under way, and its results are being made known through a number of water-supply papers that are being issued by the United States Geological Survey. The earliest of these to be prepared for distribution were a series of three (Nos. 137, 138, and 139) relating to the coastal plain which lies between the Coast Range and the Pacific Ocean. These papers did not embody close geologic determinations, but were rather records of the developments of underground waters which had taken place at the time of their issue, with some discussion of the effects of those developments in the region treated in them.

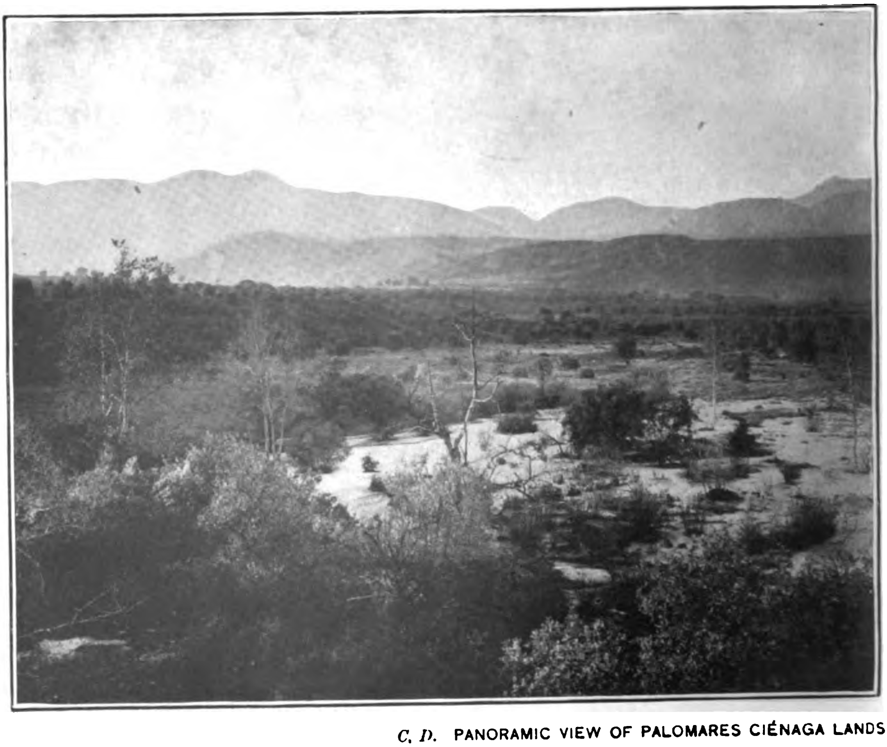
The more important data were graphically presented in maps and tables. A fourth paper (No. 142), on the San Bernardino basin, was more complete and critical, and contained, in addition to the essential hydrographic data, such significant geologic and economic information as had been brought out in the course of a rather careful general study of the valley.

The present paper is intended to continue the presentation of evidence and conclusions which are of value to water users for the important region that lies along the south base of the San Gabriel Mountains from Cucamonga westward to Los Angeles. This belt embraces a small area in the extreme western part of San Bernardino County, but lies for the most part within Los Angeles County. It includes the important communities about Ontario, Pomona, Lordsburg, San Dimas, Covina, Glendora, Monrovia, and Pasadena, and is conveniently and appropriately designated the "foothill belt." Within this area, which comprises only about 450 square miles of lowlands, there are between 55,000 and 60,000 acres of irrigated lands (exclusive of municipalities), a large proportion being in citrus fruits. This acreage ranges in value from $200 to $2,000 an acre, and may be conservatively estimated to be worth $20,000,000 or $25,000,000. In the same area there are about 40 flowing wells and nearly 400 pumping plants, representing an investment of at least $1,000,000 in wells and plants alone. There is, of course, an additional heavy investment in the connecting distributing systems. It is estimated that the pumping plants supply the equivalent of 80 to 100 second-feet of water, continuous flow, used largely for irrigation. This output is not regularly distributed throughout the year, but is largely concentrated in the dry months of July, August, and September, during which, after winters of light rainfall, the production of underground waters amounts to 300 second-feet or more.

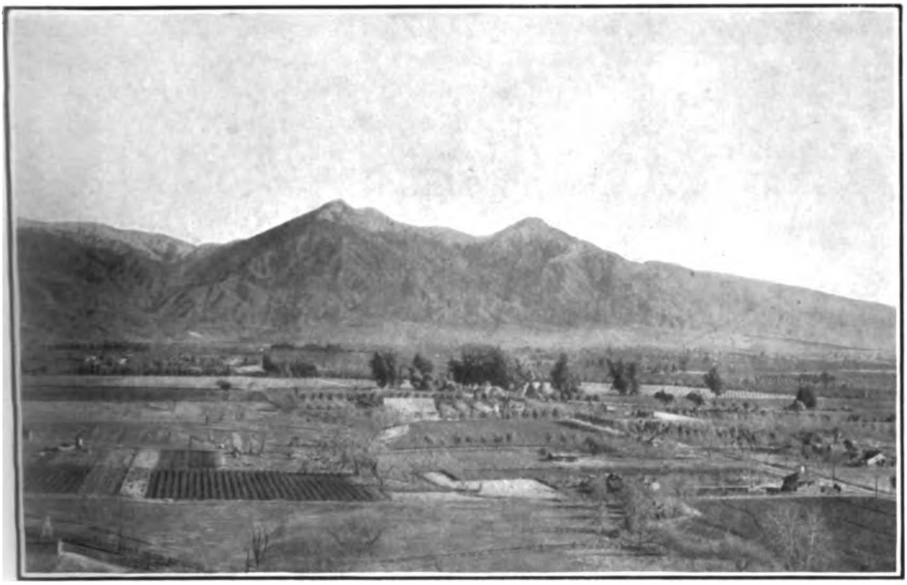
GEOGRAPHY.

The valley of southern California is a complex lowland which lies at the south base of the San Gabriel and San Bernardino ranges, opens directly westward to the Pacific, and communicates with the Mohave and Colorado deserts through Cajon and San Gorgonio passes. Its southern boundary is irregular, since in this direction finger-like extensions interdigitate with spurs of the Peninsula Range, whose main mass lies to the south; but its eastern, western, and northern boundaries are perfectly definite. The entire area of this horticultural and productive center of southern California is not more than about 3,000 square miles, yet in wealth, population, and teeming industry it is of more importance than all the rest of the State south of the Tehachapi Mountains.

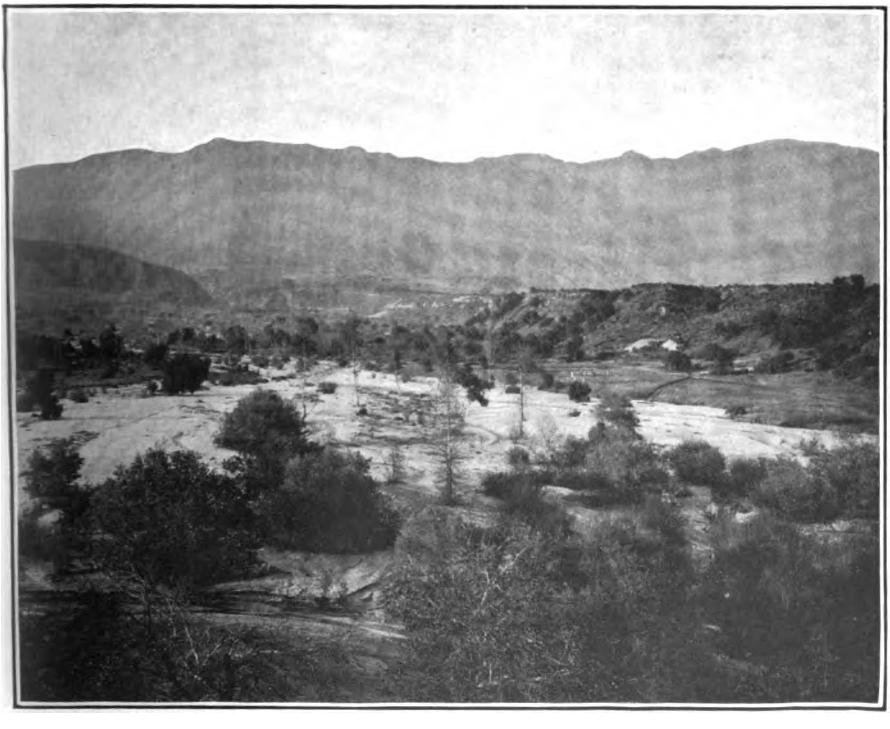
A, B. PANORAMIC VIEW OF ARR



C, D. PANORAMIC VIEW OF PALOMARES CIÉNAGA LANDS AND



Ↄ SECO ABOVE DEVILS GATE.



ᅡE SAN GABRIEL RANGE NORTH OF THE CUCAMONGA PLAINS.

The foothill belt is that part of the valley of southern California which lies along the base of the San Gabriels from Pasadena to the western edge of the San Bernardino Valley. It includes the greater part of two lowland areas, the Cucamonga Plains and the San Gabriel Valley, and the divide between them. The divide is a broad, low, interrupted pass that separates a northern outlier of the Coast Range in the vicinity of Lordsburg from the San Gabriel Range. This pass and the valley of San Jose Creek, just south of it, give the most direct lines of communication between Los Angeles and the easterly portions of the valley of southern California, about Riverside, San Bernardino, and Redlands. The Cucamonga Plains, forming the eastern section of the foothill belt, constitute a wide area of valley land, which slopes from an elevation of 2,000 feet on the upper portions of the great alluvial cones at the base of the San Gabriel Range to 500 feet at Rincon, where Santa Ana River enters its lower canyon through the Santa Ana Mountains. Eastward the plains merge without intervening physical barriers into the San Bernardino Valley.

Westward from the pass at Lordsburg the San Gabriel Valley opens. It is a rudely semicircular depression, whose base is the San Gabriel Range and whose encircling hills are the low and scattered representatives of the Coast Range. San Gabriel River crosses this semicircle as a radius from the mouth of its mountain canyon above Azusa to the Paso de Bartolo, through which it flows out upon the coastal plain. One other stream enters the San Gabriel Valley from the mountains and escapes from it by an independent canyon. This is Arroyo Seco (Pl. I, *A*, *B*), which hugs the extreme western edge of the valley, finally breaking through the hills there to join Los Angeles River at the inner edge of the coastal plain. All other streams that drain into the San Gabriel Valley from the mountains are tributary to San Gabriel River when all of their flow does not sink before reaching it.

The general surface aspect of this valley is like that of the Cucamonga Plains. The surface slopes gently, being steepest at the mountain base and flatter at a distance from it. San Gabriel Wash is the valley axis, and slopes are toward it from all directions. But in general the San Gabriel Valley slopes are less steep than those of the Cucamonga Plains, and there are within it, at the foot of the higher mountains, less extensive areas of lands too coarse and rough for cultivation.

All of this foothill belt, and many square miles of mountains north of it, are shown on three of the United States Geological Survey topographic sheets—the Cucamonga, the Pomona, and the Pasadena—drawn on a scale of about 1 mile to the inch.

GENERAL GEOLOGIC CONDITIONS.

The problems of the occurrence, the volume, the direction and rate of percolation, and the accessibility of the ground waters in any region are intimately related to the rock masses, their position, character, and attitude, and these are problems of geology. The study of ground waters, then, is in many of its phases an application of geologic principles and can not be carried out with thoroughness or success unless those elements of the geology which have a bearing on the problems are studied at the same time.

In order to make clear, therefore, the conditions which control the occurrence and circulation of the ground waters in the foothill belt, a résumé of the important geologic factors is given.

From the point of view of the water user the rock masses of the foothill belt fall into two very general classes, those which are water bearing and those which are not.

In the class of the rocks that are not water bearing are the diorites, schists, and gneisses of the San Gabriel Range and of some of the foothills. Among the latter are the Verdugo Mountains and the San Rafael Hills, and there are areas in the Santa Monica Mountains and the Puente Hills which are made up of the same dense, practically impervious rock. Such rocks are not absolutely dry. They are in places fractured and shattered, or are affected by cleavage and joint cracks in which water in small quantities may occur, but it is practically never sufficiently abundant to justify expenditures of capital in development work. Local water companies have at various times and places driven tunnels or bored wells in these rocks, but the result is invariably disappointing. The amount of water obtained does not compensate for the capital expended, and such developments are usually abandoned.

Another series of rocks, very different in origin and appearance, is also placed in this class. These rocks are the shales, sandstones, and conglomerates, usually of Tertiary age, which make up the greater part of the low hills that rise at some distance from the base of the San Gabriel Mountains. The greater part of the Puente Hills, all of the hills about Los Angeles and east of that city toward San Gabriel River, and the main mass of the Santa Monica Mountains are made up of rocks of this type.

These beds are sediments, finely stratified and folded, and they occasionally yield water in sufficient volume to be valuable. A group of deep wells west of Los Angeles, bored originally for oil, obtained water from these Tertiary sandstones. In a few wells it was under sufficient pressure to flow, but, like most waters from the oil-bearing beds, it is of rather poor quality, in that it generally carries a large proportion of alkaline salts in solution and is frequently charged also with sulphuretted hydrogen gas.

As compared with the supply in the gravel beds to be described shortly, these rock waters are negligible in quantity and wholly inferior in quality. From the practical point of view, therefore, the rocks in which they are found are to be considered as dry in this part of southern California, although here and there a successful well has been drilled in them. All these "dry" rocks have an important indirect function to perform in the storage of the ground waters, as they form the bottom and sides of the subterranean reservoirs and so confine the waters which saturate the loose gravels that fill them.

But in any study of conditions controlling underground-water supplies the important formation is the most recent one—the alluvial wash which fills the rock basins, absorbs the flood waters and the return irrigation waters, and yields these up again at lower points through springs of even flow or through artesian and pumped wells. This material is the very latest deposit in the foothill belt. It is composed exclusively of the wash from the heights which surround the lowlands. Of these heights the San Gabriel Mountains, because of their greater relief, are the most efficient and yield much the greatest amount of débris, in the coarsest condition. The lower hills south and east of the foothill belt yield comparatively insignificant amounts of relatively fine material; consequently the greatest accumulations of this alluvium are found along the bases of the higher mountains, where it is also the coarsest. But the alluvium itself is not a simple formation, which has all been deposited in one period. There are unmistakable evidences that it has originated at two different times, and that between these periods the mountain-making and valley-deepening forces were active, so that it is probable that the San Gabriel Range is higher now than when the first of this alluvium was laid down. This is a matter of importance to the water user, because the greater number of those mysterious "dikes" which are cited to account for the apparently erratic behavior of the underground circulation are due to the relations which exist between the earlier and later alluvial deposits. As a matter of convenience the alluvium first laid down will be spoken of as the earlier alluvium and that of the second period as the later alluvium.

Along the base of the San Gabriel Mountains, from Arroyo Seco eastward to the San Dimas, there are a number of benches, capped by and in many places formed entirely of the earlier gravel and clay deposits. These deposits are usually characterized by a dull-red color, due to the more complete oxidation of their constituents, this oxidation being due in turn to the fact that the red clays are older and have been exposed longer to weathering than the gray gravels and sands of the modern stream washes. These older benches usually slope steeply toward the south, and their lower margins are as a rule buried under the modern wash and are indistinguishable from it; but in some localities, as east of Eaton Wash, north of Duarte, and on either side of upper San Dimas Wash, the limit of the older alluvium is marked by an abrupt escarpment. In addition to these exposures of the red wash along the terraces at the foot of the mountains, a few low knobs of this older material lie out in the plains, projecting distinctly above the modern gray stream wash. The most conspicuous and best known of these occurrences are Indian Hill, north of Claremont, and the Red Hills, northeast of North Ontario.

The fact that this older formation occurs at so many points at a greater elevation than the later wash is evidence, although not proof, that mountain-making forces have been in operation since it was deposited, and that the San Gabriel Mountains are now higher than when it was laid down, and they hint that the correlative process—valley deepening—which so often accompanies mountain growth, has likewise been under way and has resulted in a deeper San Gabriel Valley than before.

Although this greater elevation is imperfect evidence of the continued activity of mountain-making forces, actual proof of such activity is found in one or two places, where the old alluvium has been very distinctly folded, and the attitude of its beds, originally horizontal, has been changed to vertical or nearly vertical. East of the mouth of Sawpit Canyon, in an exposure along the edge of the mesa, the red clays and gravels of the old alluvium are found nearly on edge, that is, they dip 60° or 70° S. away from the mountains; and at a number of points farther east lesser dips of 20° or 30° may be noted. These facts indicate that marked crustal movements have taken place since the deposition of the earliest alluvium. These are the movements which presumably have resulted in an increase in the height of the San Gabriel Range.

Although the modern alluvium, the gray wash which underlies the greater part of the San Gabriel Valley and the Cucamonga Plains, is the important water-bearing formation, the older wash is also of direct importance in many localities. Producing wells of value have been drilled in it in the vicinity of Laverne and San Dimas and along the northeastern slope of the Red Hills. It also has a most important indirect effect, in that an older topography—hills and valleys and plains of the older material—has been buried by the later gray wash or has been deeply cut into by the streams which have deposited it; and now these buried or partly buried old hills and valleys deflect or retard or otherwise modify the underground circulation through the later wash, which has been deposited in the older valleys and around the older hills.

These effects of the relations of the alluvium of the two periods are treated more in detail in the discussion of the ground-water conditions in each of the communities. But before this discussion is taken up it is desired to outline, in a general account of the physical geography, the origin of the mountains and valleys and their relative ages. This is a matter of scientific rather than of practical interest, although in the operation of the forces which have given southern California her marvelous diversity of abrupt and rugged mountains and fertile plains, the deep, alluvium-filled basins which are now so important as underground reservoirs have come into being.

PHYSIOGRAPHY.

GENERAL FEATURES.

The corner of Kern, Los Angeles, and Ventura counties, Cal., lies just south of Tejon Pass and near the northern edge of that great mountain area in which the Sierra proper, the northern and the southern Coast ranges, and what may be regarded as the southern representatives of the Sierra, i. e., the San Gabriel and the San Bernardino mountain masses, merge. Southwest of this mountain nodal point lies the Pacific Ocean. Northeast of it is the Mohave Desert. Toward the north the great San Joaquin Valley opens and separates the Sierra from the Coast ranges. Toward the southeast lies the valley of southern California, in a general way comparable in its geographic relations to the San Joaquin Valley, but much smaller in area and very much more complex in character and origin.

This valley consists of a number of distinct basins which are separated by physical barriers so low or so interrupted by passes that they present no serious obstacle to intercommunication between the various cultivable lowlands; but the ranges north and east of these connected basins separate them completely from the northern valleys and from the deserts and give a logical basis for grouping them together as they are grouped in commercial, agricultural, and historical nomenclature, under the collective term "valley of southern California."

As with increasing settlement the necessity has arisen for local names by which the various subdivisions of the valley could be distinguished, these have been supplied, and, as is usually the case in human occupation, they are not merely commercially convenient designations, but have an apt geographic significance which renders them quite as available for the use of the scientific geographer as for the merchant, the tourist, or the traffic manager.

The more important of these subdivisions of the greater valley are the coastal plain, between the Puente Hills and the sea; the San Fernando Valley, an inclosed basin forming the extreme northwestern lobe of the greater lowland; the San Gabriel Valley, another basin inclosed on the east, west, and south by diverging arms of the Coast Range, and abruptly limited on the north by the southern face of the San Gabriel Mountains; the Cucamonga Plains, east of the San Gabriel Basin and passing without intervening physical barriers into the San Bernardino Valley, itself the northeasternmost of the local basins; and finally the San Jacinto Valley, an irregular area drained by San Jacinto River and made up of a multitude of local valleys and intervening irregular heights.

ORIGIN OF PHYSICAL FEATURES.

In the geographic and physiographic sense this valley and its surrounding heights constitute one of the most complex areas of the State. California mountains generally seem to be the immediate products of crustal movement. Many individual ranges are to be explained as results of local uplift. In the interior of the continent and along its eastern margin heights of this character are more uncommon. There it is usual to find that individual mountain groups result from differential erosion acting on broad heights like the Appalachian plateau. In the Pacific coast region, on the contrary, mountain masses of erosional origin are unusual; the individual uplift is the rule.

As this type of mountain range is well marked and to be recognized at many places along the Pacific coast, so there is a corresponding type of valley very common here and in the adjacent deserts, less usual elsewhere, and well illustrated by the individual basins which together constitute the valley of southern California. This is the constructional basin, due, like the mountain ranges, to crustal movement instead of to erosive action. Normally the world over, valleys are due to running water—the greater valleys to long-continued erosion or to erosion of soft rocks, the minor valleys to erosive action of short duration or acting on resistant rocks. It is perhaps even less usual to find lowlands that are directly due to crustal movement than to find mountain ranges of this character, but in southern California all the important lowlands, as well as the uplands, are direct results of crustal deformation. Only the details of sculpturing—the form of the individual peaks and ridges, the canyons, the grade of the mountain streams, and the slopes of the mountain sides—are due to the subaerial erosive agents, water, ice, and wind: the mountain mass as a whole is an upthrust block of the earth's crust. Similarly, the details of the surface of the broader lowlands are due to erosive agents. Their action here, however, has been just the reverse of that in the mountain areas. There the effect of these agents has been to reduce the heights, to undo the work of the mountain-making forces. In the valleys they have deposited the materials which have been removed from the uplands, filled the original depressions, and covered the irregularities in their surfaces; in a word, they are leveling agents, and if their action were not counteracted by that of the mountain-building forces, the whole surface would eventually be reduced to a plain.

The details of the movements in which southern California's attractive alternation of valley and plain originated will perhaps never be known. Many more of them than are now available will, however, be worked out in the detailed geologic and physiographic investigations of the future. But it is possible even with our present imperfect knowledge to outline in a broad way what has happened.

In the middle and northern Sierra, where close geologic studies have been completed, it has been determined that late in Tertiary time the area occupied by the present Sierra Nevada was one of comparatively low relief, with gentle slopes and streams of moderate grade, and that the major part of the movement which has resulted in the present great range has taken place since. It is probable that the history of southern California corresponds in its broad outlines with that of the northern part of the State, and that here, until late in the Tertiary, the mountain ranges were much lower than they are now and the valleys much less deep. It is clear that the forces which have produced these mountains and valleys began to act before the close of the Tertiary period, because the latest Pliocene deposits contain gravels, widely distributed and in many places coarse. Their coarseness indicates that mountains existed near by at the time they were laid down, and their relation to the Tertiary beds whose deposition just preceded theirs indicates that the earlier beds were disturbed between the two epochs. The present mountains and valleys began to form toward the end of the Tertiary, and it is likely that they have been in process of formation ever since. In fact, it seems probable that mountain-making forces are as active on this part of the Pacific coast at present as they have been at any time since early earth history. Incidents like the Owens Valley earthquake of 1872, the San Jacinto earthquake of 1900, the great San Francisco disaster of 1906, and the innumerable minor temblors which occur from time to time are evidences of the activity of these forces. Science no longer regards it as probable that mountains originate in a night, in one tremendous cataclysm, except in volcanic regions. Ordinarily their growth is a gradual process. There are movements of a few inches, or at most of a few feet, from time to time, and the cumulative results give us mountains thousands of feet high and basins thousands of feet deep, where originally were only broad plains.

FAULT LINES.

Movements such as those just discussed, by which the highlands and lowlands are differentiated, are concentrated along lines of weakness where the crust yielded to the earliest strains. When such lines of weakness are once established, they tend to perpetuate themselves as the crust adjusts itself to later strains by yielding along the same lines. These lines of yielding are either faults—actual fractures of the crust—or flexures.

About the borders of the valley of southern California are a number of clearly defined fault lines of this character, movement along which has evidently played a commanding part in the development of the present physical features. The dominant fault of the entire region is the great fracture which extends northwest and southeast along the south base of the San Bernardino Mountains and the north base of the San Gabriel Mountains, and is a continuation of the fault readjustment along which proved so destructive to the country about San Francisco Bay on April 18, 1906. Another disturbance which for at least a part of its length is a fault line is of importance to the oil men of California, because many of the producing wells of this part of the State are found along it. It limits the Santa Ana Mountains on the northeast as far as the lower canyon of Santa Ana River, where it crosses the range and extends along the Puente Hills, near their southern edge, to the vicinity of Whittier, and perhaps farther. A third fracture of this character lies north of San Jacinto and skirts the south base of the badlands which separate the Alessandro Valley from San Timoteo Canyon. Another, somewhat less regular than those described and believed to be older in the sense that no movements have taken place along it as recently as along some at least of the others, bounds the San Gabriel Mountain mass on the south and separates it from the cultivated lowlands of the foothill belt.

It is to be understood clearly that crustal movements along these axial lines—those in an upward direction producing mountain masses, those in a downward direction resulting in basins and valleys—were probably in all cases accompanied by twisting and distortion of the surfaces thus uplifted or depressed, so that after the movement had been accomplished these surfaces were no longer approximately plane, as they probably were when the movements began. Hence the mountain tops, even before the erosion inaugurated by the uplift had destroyed the original surfaces, were probably not level, although they must have included many nearly level areas, and the basin bottoms were likewise depressed much more at one place than another, and so were very irregular.

RELATIVE AGES OF THE PHYSICAL FEATURES.

All the mountains and valleys of southern California have come into being very recently, in a geologic sense, but not all are of the same age. In a great many cases evidence either does not exist or has not been brought out to determine which of two features is the older; but in the case of the two mountain groups, the San Gabriel and the San Bernardino, the dominating mountain masses of this region, evidence apparently does exist for deciding this highly interesting question. This evidence is largely physiographic—that is, it lies in the character of the land forms and so is of a very delicate nature.

If from some commanding point like the summit of Santiago Peak, in the Santa Ana Mountains, the two neighboring ranges, the San Gabriel and the San Bernardino groups, are carefully examined, striking differences in their physical aspect at once become apparent. One seeks in vain for horizontal lines along the San Gabriel tops; a confusion of peaks and ridges of discordant and seemingly unrelated heights makes up the mountain mass. The San Bernardino range is in striking contrast with this. Its west end especially displays a long even sky line at elevations between 5,000 and 6,000 feet above the sea. On the east the broad masses of San Gorgonio Peak rise much higher.

If one enters these ranges to explore them in detail, corresponding differences are found. The San Gabriel Mountains present a labyrinth of canyons and ridges and peaks, with no level areas of any size. The ridges have narrow summits; the peaks are sharp; the streams are all evenly graded from source to mouth. In the San Bernardino Mountains, on the contrary, there are many wide upland valleys, forested and grassy glades, and lakes or playas like Bear Lake and Baldwin Lake. Where these upland levels are attained it is difficult to realize that one is actually in the high mountains. The surrounding topographic forms are rounded and gentle, the level areas are extensive, the streams meander placidly through broad meadows, and the topographic type is that of a rolling country of moderate elevation. But as the edge of these interior uplands is approached the streams plunge into precipitous canyons, the slopes are as steep as earth and rock can stand, the roads and trails twist and turn and double to find a devious and precarious way to the valleys below.

These topographic differences—the presence of broad uplands in one range and their complete absence in the other—have a definite meaning in the history of the mountain masses. The smooth forms are conceived to have been produced by long-continued erosion at relatively low levels in accordance with well-established principles, and their preservation since the mountain mass has been elevated is due to the short time that has elapsed since that event. With the further passage of time, the canyons that are now so pronounced a feature of the border of the San Bernardino mass will have extended to its very heart, and the smooth uplands that now occupy the center of the range will have disappeared. The San Bernardino Mountains will then be as the San Gabriel Mountains are now, a thoroughly dissected range. The important fact that they are not at present in this condition is regarded as satisfactory evidence that they are much younger—that is, that a much shorter time has elapsed since the elevation of the San Bernardino block into a mountain range than since the similar elevation of the San Gabriel block.

SUMMARY.

The topography of southern California in its broad features, and of the foothill belt in particular, is due to the latest crustal movements. These movements may have produced folding in rock masses, but their distinctive effect has been to originate the present relief of the country, to raise the mountains here and to depress the valleys there, the uplands and the lowlands being separated by zones of sharp flexure or of faulting.

Finally, the details of the present topography have been carved by erosion since the differential movement began. Crustal readjustments in response to internal strain, then, have produced the mountain masses and deep valleys, while contemporary and later erosion has produced the canyons and the details of mountain slopes, and has leveled the original basins into broad plains by spreading over them the material removed in sculpturing the mountain areas.

The different mountain masses, although all are comparatively recent, have not been uplifted at the same time. The San Gabriel Range is in this sense much older than the San Bernardino Range, which has come into existence as a mountain mass at a distinctly later date than its neighbor.

RAINFALL.

DISTRIBUTION AND AMOUNT.

The annual distribution of rainfall within the foothill belt is like that throughout the Pacific slope of southern California, since the entire region is one meteorological province with characteristics common to all parts. The chief of these characteristics is the division of the year into wet and dry seasons, the former including the months from November to April, and the latter the remainder of the year. The driest months are June, July, August, and September, during which practically no rain falls, and the wettest are December, January, February, and March, while April and May in the spring and October and November in the autumn serve to bridge the interval between the more pronounced seasons, a variable but generally slight rainfall being recorded for these months.

The geographic distribution of the rainfall within the province is quite as definite as its distribution in time. During the winter season, when the winds from the Pacific pass from the relatively warm ocean over the cooler land, they acquire its temperature, lose capacity to retain moisture, and drop a part of their burden as rainfall. Other things being equal, the greater the reduction in temperature they suffer the greater the rainfall; hence the mountain areas surrounding the southern California lowlands, being higher and cooler, receive heavier rains, and the communities nearer the mountains receive more than those at a greater distance from them. Thus the average at Anaheim is about 12 inches, and at Riverside about 11, while at Los Angeles and San Bernardino, nearer the mountains, the precipitation is between 15 and 16 inches.

This increase from the outlying plains toward the base of the mountains is known to be maintained as the higher parts of the mountains are approached, but exact data to illustrate this generally known fact are not available for the foothill belt, no stations being regularly maintained in the adjacent mountains.

The general character of the rainfall for the valley is illustrated by the following precipitation tables:

Rainfall, in inches, at Los Angeles, Cal.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Total.
1877-78	0.00	0.00	0.00	0.86	0.45	3.93	3.33	7.68	2.57	1.71	0.66	0.07	21.26
1878-79	.00	Tr.	.00	.14	Tr.	4.70	3.59	.97	.49	1.19	.24	.03	11.35
1879-80	.00	.00	.00	.93	3.44	6.53	1.33	1.56	1.45	5.06	.04	.00	20.34
1880-81	Tr.	Tr.	.00	.14	.67	8.40	1.43	.36	1.66	.46	.01	.00	13.13
1881-82	.00	Tr.	Tr.	.82	.27	.52	1.01	2.66	2.66	1.83	.63	Tr.	10.40
1882-83	.00	.00	Tr.	.05	1.82	.08	1.62	3.47	2.87	.15	2.02	.03	12.11
1883-84	Tr.	.00	.00	1.42	.00	2.56	3.15	13.37	12.36	3.54	.34	1.39	38.13
1884-85	Tr.	Tr.	Tr.	.30	1.06	4.64	1.05	Tr.	.01	2.00	.06	Tr.	9.12
1885-86	Tr.	Tr.	Tr.	.26	5.52	1.63	7.72	1.38	2.50	3.29	.00	.01	22.31
1886-87	.24	.21	.00	.01	1.18	.18	.20	9.25	.24	2.30	.20	.04	14.05
1887-88	.07	.00	.15	.12	.78	2.67	6.03	.77	3.15	.11	.02	Tr.	13.87
1888-89	.03	.08	Tr.	.36	4.01	6.26	.25	.92	6.48	.27	.62	.00	19.28
1889-90	.00	.61	.00	6.95	1.35	15.80	7.83	1.36	.66	.22	.03	.02	34.83
1890-91	.00	.03	.06	.03	.13	2.32	.25	8.56	.41	.26	.31	.00	12.36
1891-92	Tr.	.00	.06	.00	.00	1.99	.88	3.19	3.39	.22	2.06	.06	11.85
1892-93	.00	.01	.00	.33	4.40	4.18	6.29	2.27	8.52	.19	.06	.03	26.28
1893-94	.00	.00	Tr.	.75	.20	3.65	.94	.49	.37	.13	.20	Tr.	6.73
1894-95	Tr.	.01	.73	.02	.00	4.62	5.84	.46	3.77	.46	.19	.01	16.11
1895-96	Tr.	Tr.	Tr.	.24	.80	.78	3.23	Tr.	2.97	.19	.30	Tr.	8.51
1896-97	.02	.01	Tr.	1.30	1.66	2.12	3.70	5.62	2.31	.02	.10	Tr.	16.86
1897-98	Tr.	.00	.00	2.47	.01	.05	1.26	.51	.98	.03	1.75	Tr.	7.06
1898-99	.07	Tr.	.02	.09	Tr.	.12	2.64	.04	1.81	.18	.04	.58	5.59
1899-1900	.00	.01	Tr.	1.59	.90	.90	1.17	Tr.	.99	.54	1.81	Tr.	7.91
1900-1901	Tr.	Tr.	Tr.	.26	6.53	Tr.	2.49	4.38	.45	.68	1.50	Tr.	16.29
1901-2	Tr.	.09	.03	1.88	.46	Tr.	1.62	3.35	2.98	.16	.03	Tr.	10.60
1902-3	Tr.	Tr.	Tr.	.40	2.08	2.50	2.10	1.52	6.93	3.77	Tr.	.02	19.32
1903-4	.00	Tr.	.43	Tr.	.00	Tr.	.14	2.68	4.50	.97	Tr.	Tr.	8.72
1904-5	Tr.	.17	.28	.69	.00	2.45	2.57	6.06	6.00	.35	.95	.00	19.52
1905-6	.00	.00	Tr.	.08	2.98	.20	3.85	2.47	7.35	.69	1.02	.01	18.65

Average, twenty-nine seasons, 15.60 inches.

Rainfall, in inches, at Pasadena, Cal.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Total.
1883-84	0.00	0.00	0.00	1.30	0.00	2.73	6.10	13.21	12.99	5.93	0.77	1.90	44.[illegible]
1884-85	.00	.20	.00	.25	.89	3.95	1.22	.00	.05	3.00	.33	.11	10.0[illegible]
1885-86	.00	.14	.00	.00	7.49	2.05	7.40	2.32	2.45	4.11	.15	.00	2[illegible].[illegible]1
1886-87	.05	.26	.04	.10	1.15	.17	.19	10.66	.27	2.33	.28	.00	15.5[illegible]
1887-88	.17	.00	.33	.12	1.12	4.98	7.40	1.57	5.62	.46	.00	.00	21.77
1888-89	.00	.00	.00	.45	5.68	6.71	.09	1.08	8.83	.41	.95	.00	24.2[illegible]
1889-90	.00	.62	.00	9.31	1.45	17.17	7.92	2.66	.90	.60	.20	.06	[illegible]
1890-91	.00	.00	.26	.07	.35	3.52	.14	10.75	.68	1.84	.73	.00	18.34
1891-92	.00	.00	.09	.00	.05	2.25	1.54	3.40	4.23	.25	3.94	.00	15.75
1892-93	.00	.00	.00	.62	3.72	4.30	7.65	2.07	9.84	.47	.00	.00	28.6[illegible]
1893-94	.70	.09	.00	.80	.20	4.77	1.51	.82	.96	.13	.61	.00	10.59
1894-95	.00	.09	.85	.04	.00	7.24	8.10	1.44	4.53	.53	.25	.00	23.07
1895-96	.00	.00	.00	.32	1.30	.91	2.96	.00	3.73	.50	.17	.00	[illegible]
1896-97	.05	.15	.00	2.04	1.88	2.33	5.94	5.34	3.57	.00	.23	.00	21.53
1897-98	.05	.15	.23	2.40	.10	.26	1.50	.69	1.14	.39	1.98	.03	8.92
1898-99	.01	.00	.27	.49	.52	.64	3.18	.00	2.08	.12	1.88	.00	9.1[illegible]
1899-1900	.00	.00	.00	2.02	1.43	1.62	1.11	.00	1.55	.82	2.42	.00	10.97
1900-1901	.00	.00	.05	.34	9.80	.00	3.78	6.80	.17	1.16	1.62	.00	24.22
1901-2	.00	.00	.00	2.76	.73	.00	1.63	3.01	3.29	.38	.09	.00	11.89
1902-3	.00	.00	.00	.53	3.24	3.07	4.03	.90	9.70	3.09	.00	.00	24.56
1903-4	.00	.00	.34	.00	.00	.00	.21	3.89	4.81	.93	.01	.00	10.19
1904-5	.00	.53	.34	.96	.00	1.90	2.63	10.44	8.65	.18	1.44	.00	27.07
1905-6	.00	.00	.05	.17	2.55	.17	4.44	2.54	10.83	2.64	1.67	.00	25.06

Average, twenty-three seasons, 20.14 inches.

Rainfall, in inches, at Pomona, Cal.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Total.
1886-87	0.00	0.00	0.00	0.00	1.05	1.25	0.20	8.28	0.00	2.27	0.28	0.00	13.33
1887-88	.00	.00	.00	.37	1.25	3.56	8.33	1.70	6.63	.00	.00	.00	21.84
1888-89	.00	.00	.00	.00	4.70	6.04	.17	1.48	9.32	.87	.77	.00	23.35
1889-90	.00	.00	.00	3.85	1.82	12.59	7.10	2.56	.52	.31	.00	.00	28.75
1890-91	.00	.14	1.11	.05	.45	3.35	.13	12.78	1.16	1.67	1.02	.00	21.86
1891-92	.00	.12	.11	.00	.00	2.69	1.02	3.41	2.84	.23	3.86	.42	14.70
1892-93	.00	.00	.00	.02	3.45	2.92	7.06	3.87	10.85	.64	.22	.05	29.08
1893-94	.07	.00	.17	1.84	1.44	4.59	1.81	1.13	.95	.26	.44	.00	12.70
1894-95	.00	.00	.63	.02	.00	8.66	9.12	2.43	4.44	1.00	.38	.00	26.68
1895-96	.00	.00	.00	.05	1.36	.91	2.90	.00	4.69	.21	.03	.00	10.15
1896-97	.05	.24	.00	2.44	1.49	1.69	5.20	6.92	4.41	.00	.43	.00	22.87
1897-98	.00	.00	.25	2.84	.53	1.04	2.16	.74	1.46	.13	2.03	.00	11.18
1898-99	.00	.00	.06	.07	.06	.44	2.83	.31	2.97	.07	.07	.89	7.77
1899-1900	.00	.00	.30	1.90	1.94	1.04	1.74	.13	1.35	.80	2.60	.00	11.80
1900-1901	.00	.00	.00	.44	10.12	.00	4.22	4.81	.51	.41	1.47	.01	21.99
1901-2	.00	.00	.17	1.95	.72	.03	2.41	3.21	4.21	.46	.19	.10	13.45
1902-3	.00	.00	.00	.47	1.62	2.91	1.57	1.77	7.23	4.19	.15	.01	19.92
1903-4	.00	.02	.38	.01	.00	.01	.33	2.68	5.57	1.24	.07	.00	10.31
1904-5	.00	.23	.00	1.19	.00	1.42	3.36	8.05	8.50	1.35	2.34	.01	26.45
1905-6	.00	.00	.02	.12	2.71	.64	4.81	2.50	9.65	1.58	1.31	.41	23.75

Average, twenty seasons, 18.60 inches.

Rainfall, in inches, at San Bernardino, Cal.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Total.
1870-71	0.00	0.00	0.02	0.09	3.11	0.89	6.91	2.21	0.19	0.34	0.11	0.07	13.94
1871-72	.00	.04	.13	.60	.88	3.91	.00	2.20	.37	.79	.06	.00	8.98
1872-73	.00	.18	.04	.00	1.17	4.40	6.50	1.25	.51	.84	.21	.00	15.10
1873-74	.00	1.06	.02	.01	.74	5.73	5.51	8.76	1.08	.48	.42	.00	23.81
1874-75	.00	.00	.06	1.82	1.88	2.20	7.20	.15	.22	.07	.05	.00	13.65
1875-76	.00	.00	.00	.00	7.50	.02	6.55	1.92	3.41	.44	.03	.03	19.90
1876-77	.00	.00	.00	.20	.40	.00	3.50	4.03	.83	.26	.30	.00	9.52
1877-78	.00	.00	.00	.86	.50	3.95	3.33	6.68	2.57	1.71	.66	.07	20.33
1878-79	.07	.00	.02	.14	.05	4.70	3.59	1.00	.50	1.20	.24	.03	11.54
1879-80	.11	.02	.01	.94	3.40	6.50	1.56	1.33	1.45	5.00	.04	.00	20.36
1880-81	.00	.00	.00	.14	.67	8.80	1.40	.36	1.66	.46	.01	.00	13.50
1881-82	.00	.00	.00	.80	.27	.50	1.11	2.65	3.30	2.91	.00	.00	11.54
1882-83	.00	.00	.00	.10	.15	.45	1.60	1.10	2.82	2.95	.00	.00	9.17
1883-84	.19	.00	.53	.85	.09	2.63	1.63	12.20	9.95	5.68	3.17	.59	37.51
1884-85	.00	.00	.00	.00	.11	3.75	2.79	.11	.28	1.89	1.69	.19	10.81
1885-86	.00	.00	.00	.39	4.36	1.20	6.34	2.52	4.18	2.36	.32	.16	21.83
1886-87	.00	.00	.00	.00	.11	.61	.39	6.44	4.41	1.90	.42	.22	14.50
1887-88	.11	.04	.09	1.17	2.29	1.91	4.01	3.60	3.41	.58	.52	.03	17.76
1888-89	.00	.00	.00	.05	4.12	4.64	.93	1.50	6.55	2.05	1.13	.00	20.97
1889-90	.17	.63	.11	2.30	2.23	10.85	5.44	2.52	.89	.00	.31	.00	25.45
1890-91	.13	2.16	.88	.58	1.27	3.02	.00	7.78	.06	.53	1.67	.00	18.08
1891-92	.00	.91	.93	Tr.	Tr.	1.67	3.24	3.30	1.75	.37	2.10	.08	14.35
1892-93	.00	.00	.00	.16	1.02	2.23	4.53	3.37	8.00	.48	.03	.00	19.82
1893-94	.20	.00	.05	1.05	.30	2.28	1.26	.88	1.15	.40	.56	.00	8.13
1894-95	.00	.16	.37	.15	.00	7.25	7.39	1.14	3.44	.64	.44	.00	20.98
1895-96	.00	.00	.00	.00	1.14	.66	2.02	.00	2.92	.37	1.00	.00	8.11
1896-97	Tr.	.17	.00	2.10	.98	1.09	3.40	5.40	3.41	.08	.11	.00	16.74
1897-98	Tr.	.00	.13	2.10	.21	.57	2.10	.60	.97	.48	1.08	.00	8.24
1898-99	.00	.00	.00	.03	.05	.44	2.03	.51	3.22	.07	.19	.95	7.49
1899-1900	.00	Tr.	.01	.81	1.47	.84	.92	.00	.92	1.96	1.71	.00	8.64
1900-1901	.34	.00	.23	.36	6.10	.00	3.48	4.58	.43	.56	1.23	.05	17.36
1901-2	.00	.27	.07	1.09	.28	.04	1.65	3.02	3.89	.57	.12	.15	11.15
1902-3	.01	.00	.00	.09	1.94	1.94	1.96	1.67	6.47	3.10	.24	.00	17.42
1903-4	.00	.15	.46	.07	.00	.00	.18	2.21	5.34	.80	.16	.00	9.37
1904-5	.00	.14	.06	.32	.00	1.03	3.92	6.58	6.00	1.18	1.55	.00	20.78
1905-6	.00	.00	.13	.00	2.81	.74	2.97	2.89	8.00	1.16	.96	.22	19.88

Average, thirty-six seasons, 15.74 inches.

The San Bernardino and Los Angeles records are the longest in this part of the State, and therefore give the most reliable general averages; but since Los Angeles is near the southern edge of the foothill area, and San Bernardino about an equal distance from the mountains, these records probably express about the lowest rainfall within the district under consideration. The record at Pasadena, kept by Mr. Nelmes, covers a period of twenty-three seasons, during which the average precipitation was 20.14 inches. This average is probably somewhat higher than the final average will prove to be when that shall have been determined by longer records. This conclusion is reached from an inspection of the records at Los Angeles and San Bernardino, where the average for the last twenty-three seasons is in each case slightly greater than the average for the full period of observations. Similar reasoning indicates that the twenty-year average of 18.60 inches, now available for Pomona, is slightly below the final average which will be found for this point. Both Pasadena and Pomona, however, have heavier rainfall than Los Angeles and San Bernardino, since they lie nearer the base of the mountains; and were records available from points on the slopes and at or near the summits they would show still heavier rainfall, in accordance with the well-established fact of a progressive increase of precipitation from the mountain bases to a point near their summits.

DEPENDENCE OF WATER SUPPLIES ON RAINFALL.

The significance of the annual rainfall to the irrigating communities lies in the direct and immediate dependence on it of the surface run-off from each of the mountain drainage basins and in the less immediate but not less important or final dependence of the underground reservoirs on it for recharge.

The marked contrast between the summer and winter run-off from the mountain canyons, with its unfavorable effect on irrigation possibilities and on the recharge of subterranean reservoirs, is of course due primarily to the division of the year into two seasons, a wet and a dry, with strongly contrasted precipitation; but other factors also exert a pronounced influence, and it so happens that nearly all of them in southern California are unfavorable to uniformity of flow. Among these factors are the length and character of drainage lines, the steepness of slopes and of stream channels, the character of the rocks in a drainage basin, and the condition of the forest and brush cover over the slopes.

Where drainage lines are short and direct and channels are straight instead of tortuous, a minimum of time is required for the passage of a given flood wave from the headwaters of the stream to its mouth, and so there is but a limited opportunity for the absorption of water by porous rocks and débris to be released later as summer flow.

A closely related factor is that of steep slopes and stream channels. The process of absorption of water by soil and rocks is a slow one and is controlled by the rate of percolation through the soil, away from the saturated surface, and by the length of the period of saturation. From steep slopes and stream channels of high gradient the water escapes quickly, so there is but little opportunity for its absorption. The streams of the San Gabriel Mountains that drain into the foothill belt have relatively short and direct courses, and the slopes in this mountain range and the grades of the streams are especially steep. These conditions result in extremely rapid run-off in heavy floods of very short duration.

The influence exerted by the type of rock in a drainage basin is also most marked in its effect on the character of the run-off. Loose sandstones absorb water like sponges, to yield it slowly at some lower point, perhaps in a distant drainage basin. Cavernous limestones may offer tortuous underground passages through which water escapes slowly. But dense granitic and metamorphic rocks have little absorptive or storage capacity unless they are extensively shattered, and such water as falls upon them is usually shed promptly. By far the greater part of the San Gabriel Range is made up of rocks of these nonabsorptive types.

Finally, the various cover growths are of great importance in modifying run-off. Trees and brush act in many ways to this end.

They hold loose fragments of rock by their binding root systems, so that they are not carried down to the stream channels so soon. The crevices about the rock fragments which are thus held become little storage reservoirs. The trees also aid in making these crevices by the prying action of their roots and by the disintegrating action of the vegetable acids which are yielded by their decay. The various growths build up a porous absorptive soil by the litter which they shed and the rock sand which becomes enmeshed in their roots, and they protect the soil which thus accumulates and prevent it from being swept away. Finally, they interfere directly with run-off by the obstacles which their roots, stems, and fallen leaves and branches offer to the flow of water over the surface. In all of these functions the immediate escape of rains as sudden floods is checked, and their absorption to be slowly released later is encouraged. The effect of forest and brush cover, then, is to decrease the violence of winter floods and to maintain the stream flow during the crucial summer irrigating season. Forest cover throughout the San Gabriel Mountains is in bad condition through the recurrence of destructive fires during past centuries. Systematic efforts are now being made by the United States Forest Service and by the State forester to improve these conditions by preserving from further destruction such covered areas as remain and by extending timber growth through tree planting. These efforts are for the benefit of the southern California communities which depend on the water supply from the mountains, and are deserving of their heartiest support and most earnest cooperation.

The statement has frequently been made that the underground waters are just as dependent as the surface run-off on precipitation within the local contributing drainage basins, but the tenacity of the oft-asserted belief that these subterranean reservoirs have some other source than local rainfall makes it desirable to repeat this statement with emphasis. Each of the important subterranean basins in southern California is supplied exclusively by the water which falls upon its surface or flows into it through some tributary stream. Any other hypothesis, as, for example, that waters from the distant Sierra or Colorado River or Pacific Ocean may, by underground channels or by seepage, reach the San Gabriel Valley or the Pomona neighborhood, is erroneous, and conclusions based on it are wrong and lead to a false policy in the utilization of the ground waters.

The permanence of the underground reservoirs as sources of water supply is dependent on all the conditions which have been outlined as affecting surface run-off, because, as just stated, it is the surface run-off from the mountain areas which must be relied on to recharge these reservoirs; and, in addition, whatever makes this surface run-off erratic—extremely high in winter and extremely low in summer—not only makes it less effective in the recharge of the underground basins, but increases the summer drafts on them. A discouragingly large proportion of the greater floods escapes entirely to the sea. These floods can not be used by the surface systems, and they pass over the gravels of the valleys too rapidly and in too great volume to be fully absorbed, and so are largely wasted. It is obvious that whatever will reduce the violence of floods will lessen the total loss of waters by surface flow to the sea and will make more effective the restoration of ground-water levels.

These levels suffer in still another way at the present stage of development of the country, by the concentration of the run-off in the winter months and its reduction to a low point during the irrigating season. Since the discovery in the nineties that large bodies of ground water were available for irrigation, there has been a constant tendency to extend acreage beyond the amount which can be covered by the summer surface run-off and to make up the deficiency during that period by pumping. When the summer flow is especially low and continues low for a long period, the pumping season is greatly extended and the drafts on the underground basins are proportionately increased.

To sum up: The available quantity of ground waters is adversely affected by whatever tends to make surface flow more erratic. This effect is brought about in two ways—first, by the large proportion of waters which escape wholly when winter floods are violent; and second, by the greater drafts on underground sources made necessary when summer run-off is low.

STORAGE FACILITIES.

The canyons in the San Gabriel mountain range are too narrow and too steep for storage sites, except of very inferior capacity and excessively high unit cost, and the run-off is so erratic that to be effective reservoirs must be of exceptional capacity. The recorded flows of San Gabriel River vary between a minimum of 3 second-feet and a maximum of 11,130 second-feet; and the total estimated annual discharge since systematic records have been kept varies from a minimum of 10,489 acre-feet to a maximum of 164,700 acre-feet. These minima are probably nearly absolute, since they were obtained during the seasons of lowest rainfall known in southern California; but greater maxima than those given were undoubtedly reached during the season of 1883–84, when the precipitation was nearly twice that of any winter since the stream flow has been accurately measured.

With such widely varying annual run-off, reservoirs capable of storing enough water to supply the tributary lands during two seasons, at least, would be required for safety. Such reservoir sites do not exist in the San Gabriel Mountains.

MEASURES FOR CONSERVATION OF WATERS.

In the lack of surface reservoirs, such minor helpful measures as are possible must be taken to prevent the present distressing waste of flood waters. Restoration of forest and brush cover is one of the most effective of these, although it accomplishes results but slowly. Gradually through reforestation summer flow should be increased and the volume and suddenness of winter floods somewhat lessened. Another measure which is practiced in a small way is the spreading of flood waters over the sand and gravel areas about the canyon mouths, so that they may be more fully absorbed and thus may increase the ground-water supply.

With certain important modifications, the simple principle that the quantity of water absorbed varies with the area of the flooded surface and with the time that it is covered is the basis of this work. If the character of a given flood channel can be so altered that the water in its escape covers twice the normal area, the amount absorbed will be increased twofold; and if the flow can be checked so that twice the normal time is required for the passage of the water between two points, absorption is again increased twofold. These are general terms, of course, and would be strictly true only if the flood waters were clear and if drainage from the flood channel were so free that the water could always escape as fast as it is absorbed. Neither of these conditions holds. Early flood waters are filled with fine suspended matter which is deposited as the water seeps into the river bed, and which soon forms a coating of but slightly permeable slime that tends to prevent absorption. Toward the end of a flood stage, when the water is clear, this slime is washed away and absorption becomes more effective.

In those parts of the flood-water channel which lie at some distance from the base of the mountains, where the ground-water plane is near the surface, rapid absorption in the stream channel quickly raises the ground-water plane locally, so that the stream is then flowing, as it were, upon a saturation ridge, and further absorption can take place only as rapidly as the waters can percolate away from this ridge. The practical result of this principle is that the first part of a flood is more effectively absorbed than the latter part, and the first floods at the beginning of a rainy season are more effectively absorbed than those which come later in the winter.

These are important practical modifications of the rule that absorption varies with absorptive area and time. In the application of this rule, flood waters are distributed over as large areas as possible near the heads of the alluvial fans, and the rate of their flow is checked as much as possible. The most effective work of this character that has been done thus far in southern California is that by the Riverside companies in Santa Ana Wash above San Bernardino. Here for some years minor floods have been checked by temporary dams, and the water has been distributed in a small way over the sands of the river wash, with what the engineers in charge regard as excellent results. Similar work on a less extensive scale has been done by the Ontario companies on the Cucamonga fan and in the lower canyon of San Antonio Creek. The great difficulty in work of this kind is to unite the interests to be benefited, so that they will support a work whose results are not easy to demonstrate. But as water becomes more valuable in southern California, and as the direct dependence of the underground reservoirs on recharge during the rainy season becomes more clearly understood, it will be less difficult to unite these interests in a concerted movement to aid in the necessary engineering work.

ABSORPTIVE CAPACITY OF SANDS.

The absorptive capacity of the sands and gravels of varying coarseness in the different portions of an alluvial fan is a subject of debate, and the general opinion among engineers seems to be that absorption takes place most effectively and readily in the sands which occur in the lower part of the stream channel. When the size of the soil particles remains uniform, the transmission capacity of a mass increases with the square of the diameter of the individual particles. The size of the pores, although not the percentage of the open space, increases, and the effect of friction is greatly reduced with this increase. Percolation thus approaches flow as the sand or soil particles become larger and larger. In nature, however, sands rarely consist of particles of uniform size. They are usually heterogeneous mixtures, and their transmission capacity can be determined only by measurement. The effect of mixing particles of a larger size with a uniform sand is thus summarized by Slichter:[a]

> If to a mass of nearly uniform sand particles larger particles be added, the effect on the resistance to the flow of water will be one of two kinds, depending principally upon the ratio which the size of the particles added bears to the average size of the grains in the original sand. If the particles added are only slightly larger than the original sand grains, the effect is to increase the capacity of the sand to transmit water, and the more particles of this kind that are added the greater will be the increase in this capacity. . . . If, however, large particles are added, the effect is the reverse. If particles seven to ten times the diameter of the original sand grains be added, each of the new particles tends to block the course of the water. Thus, for example, a large bowlder placed in a mass of fine sand will tend to block the passage of the water. As more and more of the large particles are added to a mass of uniform sand, the rate of flow of water through it will be decreased until the amount of the large particles equals about 30 per cent of the total mass. From this time on the adding of the large particles will increase the capacity of the whole to transmit water, until, if a very large quantity of the large particles be added, so that the original mass of fine particles becomes relatively negligible, the capacity to transmit will

---

[a] Slichter, C. S., Water-Sup. and Irr. Paper No. 140, U. S. Geol. Survey, 1905, pp. 10-11.

approach that of the mass of the large particles alone. These facts have an important bearing upon the capacity of gravels to furnish water to wells or to transmit water in the underflow of a river. The presence of large particles is not necessarily to be interpreted as indicating a high transmission capacity of the material, for this is indicated only when the large particles constitute a large fractional per cent of the total mass, as would be the case where the large particles equal 40 or 50 per cent of the whole.

In an earlier paper[a] Slichter gives an interesting table showing the rate of percolation through transmitting media of different sizes under fixed conditions. From this table the following is adapted. A uniform size of grain, a standard porosity of 32 per cent, and a temperature of 50° F. are assumed in each case.

Rate of percolation of water through different kinds of soil.

Kind of soil.	Diameter of soil grains.	Velocity with a gradient of 100 feet per mile.
	Inch.	*Feet per year.*
Silt	0.0012	12
Very fine sand	.0028	66
Fine sand	.006	304
Medium sand	.014	1,650
Coarse sand	.03	7,577
Fine gravel	.12	121,229

When the soils are of uniform grain, therefore, the rate of percolation increases as the square of the diameter of the soil particles and the amount of water transmitted increases in the same ratio. Coarse material is therefore very much more effective than fine as a transmitting medium, when the sizes are not mixed. In alluvial fans, however, there is always mingling of coarse and fine material, but the average and probably the effective size of grain is usually much greater at the head of a fan than near its margins, and the transmission capacity is therefore believed to be greater near the head. To take advantage of this condition, distribution of flood waters should be effected at as high a point on an alluvial fan as is practicable, because absorption will be much more rapid at such a point. In some places it may be that the rough, bowldery condition of the head of the fan and the steep grades which exist there will counteract the advantages, and as a practical measure it will be advisable to effect the distribution at a lower point; or bed rock may lie near the surface, as in the Mill Creek fan and perhaps that of the Santa Ana in San Bernardino Valley, practically preventing rapid absorption. Where such conditions exist it is of course necessary to build the distributing works at lower points. So far as is known, however, bed rock does not lie near enough to the surface under the fans of the foothill belt to have an unfavorable effect. Steep grades and rough ground for constructing distributing canals are the only adverse elements to be considered here.

---

[a] Slichter, C. S., Water-Sup. and Irr. Paper No. 67, U. S. Geol. Survey, 1902, p. 27.

ABSORPTION ESTIMATES.

The rate and the total amount of the recharge of the subterranean basins through the absorption of flood waters are exceptionally difficult to determine, because accurate measurements of floods are almost impossible to make on account of the steep grades and the indefinite channels that exist across the alluvial fans. But few data are available on the subject, and while theoretical considerations give indications as to what is happening, they can not generally be supported by figures.

In southern California one set of absorption measurements was made on two minor floods in the spring of 1903 by W. B. Clapp,[a] hydrographer, of the United States Geological Survey, and while Mr. Clapp does not regard his measurements as satisfactory, because of the small force and the limited time at his disposal and the inherent difficulties of the work, they yet give certain concrete conceptions of what takes place during the flood periods.

During the twenty-four hours of April 26, 1903, San Gabriel, San Dimas, Dalton, Santa Anita, and Eaton canyons discharged 757 acre-feet of undiverted waters into the San Gabriel basin, 454 acre-feet of which passed the bridge at Elmonte and was lost, while the remainder, 303 acre-feet, was absorbed by the gravels and joined the body of underground waters in the basin. On May 23 of that year the same streams discharged 225 acre-feet of undiverted waters, and all of this except the small amount lost through evaporation was absorbed, none passing the Elmonte bridge. During the two periods of measurement water was being returned to the San Gabriel Valley underground reservoir at the rate of 153 and 113 cubic feet per second.

These measurements were not made during the period of highest water. A flood with a discharge of about 1,220 second-feet occurred on April 17, nine days before the first measurement, and the flow in the San Gabriel slowly diminished from that time until long after the date of the second measurement.

Inasmuch as no calculation has been made of the diverted water used in irrigation, which in the San Gabriel systems was from 20 to 70 second-feet throughout the year, and a part of which was absorbed and returned to the ground waters, nor of the greater absorption during the heavier floods, nor of the rainfall over the San Gabriel Valley, which sinks directly as it falls and does not appear as run-off, nor of the hundreds of minor unmeasured rills which enter the basin during storms, perhaps one or the other of the figures given above may be not far from the average annual rate of recharge. Some slight additional weight is given to this assumption from the fact that the San Gabriel flow at the time of the last measurement was 167 second-feet, which is not far from the annual mean of 148 second-feet for 1903.

---

[a] Hoyt, John C., Water-Sup. and Irr. Paper No. 100, U. S. Geol. Survey, 1904, pp. 339 et seq.

In the Paso de Bartolo, San Gabriel Valley ground waters rise in springs at the rate of 65 to 85 second-feet during the irrigating season. In addition, a considerable amount of water must pass into the air from the moist lands above the pass, by evaporation. This is ground water which is brought to the surface by capillarity and there evaporated, wherever the ground-water plane lies within a few feet of the earth surface. In addition, a certain amount of ground water escapes through the Paso de Bartolo as underflow without reaching the surface at all, Slichter,[a] using rather meager data, has estimated the amount of this underflow at 92 second-feet. This, added to 75 second-feet assumed as a mean of the spring waters, gives 167 second-feet of escaping ground waters, without reckoning evaporation or waters pumped for irrigation. These escaping waters must be about equal to the average annual recharge. It seems likely, then, from this consideration of the broad probabilities in the case, that a recharge of the San Gabriel Valley underground reservoirs takes place at a rate equal to a continuous flow ranging between 100 and 200 second-feet, and that, of course, drainage is affected at an equal average rate.

CHARACTER AND CONDITION OF SUBTERRANEAN RESERVOIRS.

The origin of the great reservoirs which are now so extensively drawn on in irrigation has been discussed in general terms in the section on physiography (pp. 13–18), but a résumé is introduced here preliminary to a more minute treatment of water levels. These reservoirs are irregular rock basins, due to the warping of the earth's crust as a result of those stresses to which it is continually subject. The Pacific coast region of the United States has of late been especially affected by such stresses, and its mountains and valleys are to a great extent due to them. The great interior valley of San Joaquin and Sacramento rivers is the most impressive example of a deep and extensive basin formed in this way, and the Sierra Nevada east of it is equally impressive as an example of a mountain range whose origin is to be sought in crustal movement. Earth stresses in the vicinity of the valley of southern California clearly have been most complex, resulting structures are irregular, and the final product has been a number of distinct rock basins irregular in trend and outline, each of which is an underground reservoir more or less extensively drawn on for irrigating waters. Among the more important and best known of these basins are the San Bernardino Valley, the San Jacinto Valley, the Cucamonga Plains, the San

---

[a] Slichter, C. S., Water-Sup. and Irr. Paper No. 140, U. S. Geol. Survey, 1905, p. 54.

Gabriel Valley, the coastal plain, and the San Fernando Valley. All of these are distinct, each has its own water supply, and the ground waters of each are used for irrigation, either within the basin or on accessible lands outside it.

Each of these rock-floored and rock-rimmed reservoirs is filled with loose material, sand, gravel, or clay, which has been eroded from the mountains as they rose and carried by the streams to the basins as they sank. This filling has been distributed over the basins in a rather even way, so that the present surface of each of them is a plain, usually with a gentle slope away from the mountains, the source of the material.

THE GLACIAL HYPOTHESIS.

Inasmuch as there is a rather widely prevalent idea in southern California—an idea which has been frequently presented in suits at law—to the effect that these sands, clays, and gravels are glacial in origin, it is perhaps worth while to present here the facts which make such a hypothesis untenable.

Students of glaciated regions have come to recognize certain phenomena as characteristic of ice-molded areas. Some or all of these evidences are invariably present where ice in glacial form has covered a region. Their complete absence in southern California leads at once to the setting aside of this theory.

Extensive glaciation in mountain valleys molds them into U form, cuts cirques at their heads, scars their walls and bottoms with striæ, and leaves moraines along their slopes and out on the plains beyond the mountains where the ice streams ended. None of these evidences are found in the valleys of the San Gabriel Mountains.

Ice flowing over mountain uplands or relatively smooth rock-floored plains shears off all rock protuberances, polishes the projecting surfaces into roches moutonnées, sweeps away rock-disintegration products, gouges out basins, which may later become lakes, and leaves in its retreat erratic bowlders that may have been carried across divides from distant sources. The San Gabriel Mountains, instead of exhibiting these phenomena, have many projecting rock pinnacles, are covered with the detritus of rock decay, are free from rock basins and lakes, and have only bowlders of disintegration scattered over them.

If glaciers ride out upon the plains in front of the mountains in which they originate, they leave irregular heaps of unsorted rubble, angular bowlders, a hummocky topography, and deposits of till, a compact clay containing scattering glaciated rock fragments. The plains at the base of the San Gabriel Range are clearly unlike this. They are a series of typically developed alluvial fans; graded as stream-laid deposits always are, with waterworn but unstriated bowlders, progressively finer as the distance from the mountains increases, and free from lakes or undrained depressions. There is no evidence whatever of glacial action in the material of which they are built up nor in its arrangement. Water has been the agent by which this material has been transported from its original position in the mountains to its present resting place in the basins, and in consequence the sands and gravels have always been saturated below a point where they could drain freely. This saturating water is in constant slow motion from the point where it enters the gravels, along some stream channel or at the mouth of a mountain canyon, to the point where it escapes from the basin over the lowest part of its rim. Its movements are impeded by the friction which it encounters in its passage through the fine pores, so that its surface is not level like that of a free body of water, a lake, or a sea, but slopes from the point of supply to the point of drainage. When supply is increased the slope is steepened by raising the surface of saturation at the point of intake. When supply is decreased by a lessened rainfall, the slope of the surface of saturation becomes flatter and the ground-water level falls, the lowering being more marked at a distance from the point at which the basin drains; for since this latter point controls the escape of water in the basin, its level remains practically constant.

CHARACTER OF THE ROCK FLOOR OF THE FILLED AREAS.

The surface of basins like the San Gabriel Valley or that east of the San Jose Hills is invariably a sloping plain, steeper near the mountains, more nearly level at greater distances from them, and varied only by minor knobs or local changes of slope. Red and Indian hills rise above the Cucamonga Plains; a number of bed-rock knobs in the neighborhood of San Dimas and Glendora project above the plain of waterworn material which lies between the San Jose Hills and the San Gabriel Mountains; San Dimas Wash, itself a late sand and gravel filling, lies between bluffs of older alluvium; the Raymond Hill "dike," which extends from Pasadena to a point beyond Santa Anita, is marked for much of the distance by an abrupt change of slope and in places by distinct knobs; and here and there at other points near the edges of the plain bed-rock knobs of shale or of gneiss rise above the general valley level. These projections are sufficient only to indicate the irregularity of the valley bottom; they do not enable us to restore the details of the irregularities. Well records generally do not indicate that bed rock has been reached in the borings, the wells usually being too shallow to accomplish this result. The deepest within the San Gabriel Valley—one drilled by

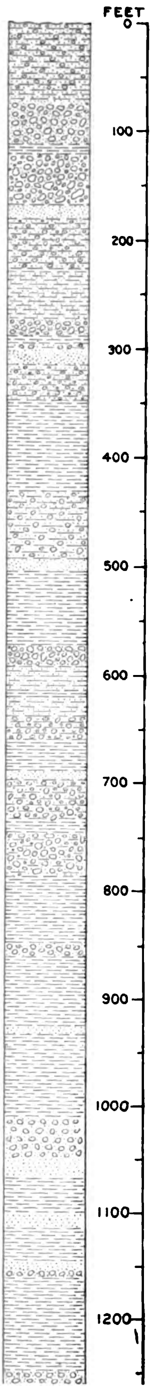


FIG. 1.—Section of well north of Woyden (No. 204, Pasadena quadrangle).

the East Whittier Company (fig. 1), north of Woyden station on the Southern Pacific Railroad—is 1,260 feet deep, and no bed rock was encountered, although the bottom of the well is almost 1,000 feet below sea level. Among the wells in the vicinity of Pomona of which records have been obtained are a number between 500 and 1,000 feet deep. One of the deep wells of the Irrigation Company of Pomona, situated in the old Palomares ciénaga, about three-fourths of a mile northeast of the point of the San Jose Hills, reached bed rock at a depth of about 800 feet. It was drilled 150 feet lower, but of course no water was developed in the deeper formation. Bed rock in this well is about 150 feet above sea level, as the surface of the plain here is about 950 feet above.

The Lorbeer well, 1 mile northwest of Chino, is 973 feet deep and extends nearly 200 feet below sea level without striking bed rock. The lower 500 feet of clays, many of them red and of cemented gravel. were dry and yielded no water. These strata appear to belong to the earlier alluvium rather than to the later, more effective water-bearing gravel series.

Half a mile southwest of this, a well belonging to Black Brothers & Woodhead is 718 feet deep and extends to within 25 feet of sea level. An incomplete record of this well fails to show the presence of strata older than the modern alluvium.

Some other wells near bed-rock hills strike the buried slopes of these hills, but generally those out in the plains and valleys penetrate only loose sands, gravels, and clays.

It may be accepted as true that the bed-rock bottoms of the valleys whose topographic details are concealed by the mantle of wash which forms the Cucamonga Plains and the San Gabriel Valley are irregular, just as the topography of those bed-rock areas which extend above the wash as hills is irregular. The rock basement beneath the San Gabriel Valley is presumably not unlike the hill region between Los Angeles and Pasadena in character.

An attempt to estimate the elevation of bed rock in the deepest part of the San Gabriel Valley is interesting but speculative. Since it is a valley of deformation, not one of erosion, a consideration of stream grades throws no light on the problem. A projection of the mountain slopes on the north and south of the valley to some assumed point of greatest depth probably gives a maximum measure, since it is quite unlikely that the steep slopes of the unburied portion of the surrounding mountains are maintained for greater distances beneath the cover of wash than above it. Such a rude estimate gives 4,000 feet below sea level as a possible depth of the bottom of the San Gabriel basin 2 or 3 miles south of Monrovia. It is likely to be less than this. The deepest well in the basin is that owned by the East Whittier Land and Water Company. This well is just west of San Gabriel Wash and about one-fourth mile north of the main line of the Southern Pacific. No bed rock was encountered in it at a depth of 1,260 feet, or nearly 1,000 feet below sea level.

The Cucamonga Plains east of the San Jose Hills represent a more extended area than the San Gabriel Valley, and bed rock may be buried to a considerably greater depth beneath them. Wells in this area whose records have already been quoted extend to points well below sea level without encountering rock, but the outcropping Red Hills and Indian Hills, the barriers to which are due the old Martin and Del Monte ciénagas, the dry red clays and cements encountered in some of the deep wells between Pomona and Chino, and the traces of earlier alluvium which flank the west end of the Jurupa Mountains on the north, indicate that this formation may be of considerable importance under at least the western portion of the Cucamonga Plains. Beneath the northeastern part of these plains, where the alluvial fans are so steep and high, water is at too great a depth to be accessible, the underground conditions are little known and of little interest, and the depth to the bottom of the basin is purely a matter of conjecture. It has been estimated[a] that the San Bernardino basin may be 3,000 feet deep, or thereabouts. It seems unlikely, from the general evidence which has just been given, that the San Gabriel basin is more than 4,000 feet deep, and it may be less than this. The Cucamonga Plains area may overlie a bed-rock basin that is somewhat more deeply buried than either.

GROUND-WATER DISTRICTS.

Within the foothill belt the development of ground waters has been most intense in certain districts where experience has proved it to be most accessible and present in greatest amount, or where, despite the rather high cost of production, the crops raised by its use are valuable enough to bear easily the expense of pumping against high lifts. It is intended to present in the following paragraphs the essential facts, so far as they are known, as to the occurrence of the waters in each of these areas.

---

[a] Water-Sup. and Irr. Paper No. 142, U. S. Geol. Survey, 1905, p. 31.

RED HILLS WATERS.

The "Red Hills," so called, lie about 2 miles northeast of North Ontario and nearly 4 miles south of the base of the San Gabriel Range. As a physical feature they form a nearly flat-topped mesa, which interrupts the general slope of this part of the Cucamonga Plains. Approached from the north the mesa appears only as a lessening of the slope, but its southern edge is a scarp 50 to 150 feet high. The hills are made up of a deposit of the earlier red alluvium which has here escaped the destruction of the older topography by erosion during the deposition of the later alluvium. The low mound therefore represents the top of a hill of red clay, sand, and gravel, whose slopes are deeply buried under modern wash (fig. 2). Indian Hill represents a similar outcrop, and the same red-clay formation is reported to show

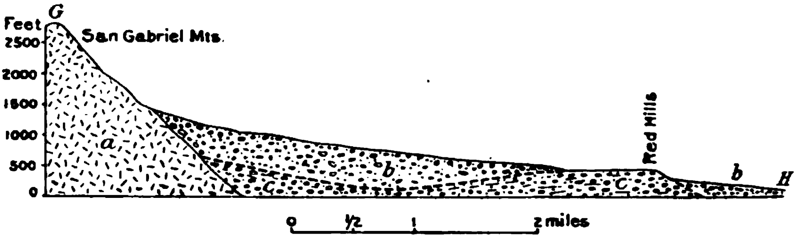


FIG. 2.--Diagrammatic section through the Red Hills; *a* granitic rocks; *b*, *c*, earlier and later alluvium and hypothetical boundary between them.

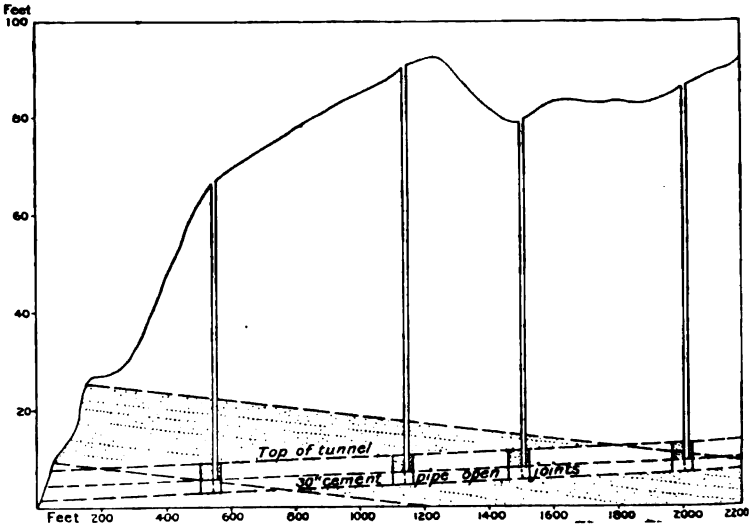


FIG. 3.-Section along line of the Eddy or Cucamonga tunnel.

between these two points. The Martin and Del Monte ciénagas are likewise probably due to buried hills of this older deposit which approach near to the surface. Its distribution beneath the modern gray alluvium therefore appears to be extensive.

This buried earlier alluvium affects the occurrence of underground waters in two ways. In the first place, where the hills of the older, concealed topography lie athwart a line of underground circulation through the later alluvium, they serve as a dike or underground dam, forcing the waters which are percolating through the overlying gravels to or near to the surface, where they flow out in springs or are easily developed by wells. Or again, where the older alluvium lies near the surface the waters which circulate through it may be brought within reach of development. As the older alluvium has been folded in some localities by crustal disturbances which have taken place since its deposition, it may be that where it projects above the general plains surface it has been brought to this position by folding. The section of the Eddy tunnel through the base of the Red Hills near their western margin (fig. 3) seems to show a dip of the beds toward the north. It is probable, therefore, that this body of older alluvium stands above the general plain because it has been brought up along or near the axis of such an arch. Some of the waters which are percolating through it southward from the base of the San Gabriel Mountains will be brought to the surface at this point and will issue as springs, or where their volume is not great enough to force them out as springs, they will at least be brought near enough to the surface to be accessible and may be developed by pumps.

As a matter of fact, the vicinity of the Red Hills has been a source of irrigation water since the settlement of this part of southern California. Originally the waters utilized rose to the surface, principally in the "East" and "West" ciénagas. The West ciénaga lay along the west base of the Red Hills and the East ciénaga in a ravine which drains southward from a point east of the highest part of the mesa, but near the center of the outcrop of the red alluvium.

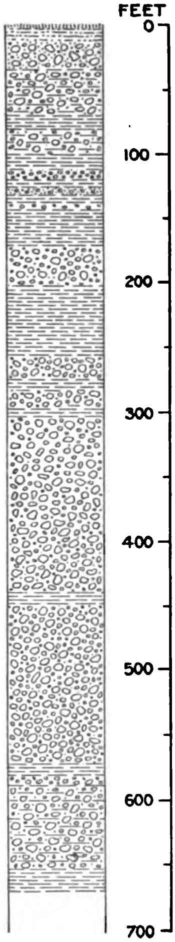


FIG. 4.—Section of Cucamonga Water Company's well (No. 69, Cucamonga quadrangle).

As the colonies dependent on these waters expanded, several devices were adopted for increasing the output of the water-bearing land.

The Y tunnel was driven into the hill east of the East ciénaga in 1886 and 1887. Another tunnel, three-fourths of a mile farther east, was driven into water-bearing ground in 1887 and 1888, and the Eddy tunnel was extended under the West ciénaga at about the same time. More recently, especially in the late nineties and since, many wells have been drilled and pumping plants installed to increase or to maintain the original supply.

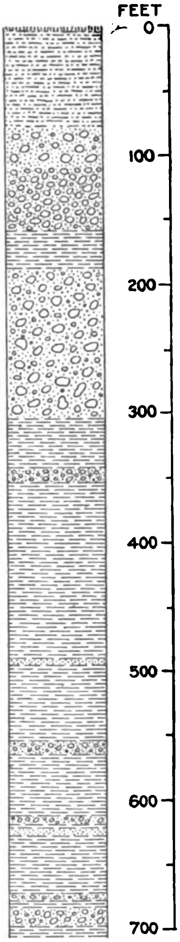


Fig. 5.—Section of Sunset Water Company's well (No. 54, Cucamonga quadrangle).

The original ciénaga waters and the pumped waters which now take their place seem certainly to be derived both from the earlier and later alluvium. The ultimate origin of the water in each of these formations is the same—namely, the rainfall upon the San Gabriel Range, north of the Red Hills—but the courses which they follow to the point of development, or at which they originally issued, are probably essentially different. Nevertheless, waters from both sources were no doubt mingled in the old springs and are probably now mingled in some of the wells.

It is to be remembered that the Red Hills as a partially buried topographic feature act as a barrier against which the modern stream wash has been piled. (See fig. 2.) The waters which are percolating southward through this wash reach the barrier, rise behind it, and flow over it as springs, except where they are taken out by development before they reach the surface. Waters within the older formation, the red alluvium of the hills, enter the porous beds of this terrane at points near the base of the mountains, follow a deeper and presumably longer course entirely below the modern wash, and rise along the fold which is expressed by the Red Hills, to escape as springs or to be taken out before their escape by development. Important evidence of this difference in the courses followed by the two groups of waters is furnished by their temperatures. The waters of the east-side wells issue at temperatures of 70° to 72°; those of the west-side wells have temperatures of about 64°. This difference of 6° or 8° indicates that the former waters rise from regions 350 to 400 feet deeper than the latter, if the usual increment of 1° increase in earth heat with each 60 feet in depth is accepted as applying in this region. Inasmuch as the increase is probably less rapid than this in these unconsolidated gravels, it is likely that the difference in the depth from which the two waters rise is greater than that given above. If this evidence of the temperature is accepted as a safe basis for a division of the waters, the Haskell wells (No. 79, Cucamonga quadrangle) and those farther east fall into the group which derives its waters from the Red Hills formation, the older alluvium; while those to the west derive their waters from the overlying modern wash. The location of the wells in areas which are recognized as respectively in older and in modern alluvium supports this evidence of the temperatures.

It is unlikely that the waters of the two groups are wholly distinct. Interchange probably takes place through leakage from one formation into the other. However, even though the separation is not entirely perfect, it is probably sufficiently definite to bring about certain differences in the behavior of the two groups of waters under the influence of development. The supply in the west-side wells may be expected to respond somewhat more promptly to wet and dry years than that of the east-side wells, whose waters follow a longer course through somewhat less pervious material to the point where they are pumped to the surface. In many places, also, the older gravel is less open and yields its waters less freely than the newer, so that individual wells are expected on the average to have a smaller capacity. The water developed from both formations in the vicinity of the Red Hills is probably supplied largely by the run-off from Cucamonga Canyon and the canyons farther east.

SAN ANTONIO UNDERGROUND WATERS.

The area whose ground waters are supplied by run-off from San Antonio Canyon is so distinct and so important that it is best to accord it separate treatment. The Palomares, Del Monte, and Martin ciénagas, at one time prolific sources of artesian water and still yielding valuable pumped waters in large quantity, the Indian Hill group of wells, and another series of scattered wells near the San Gabriel foothills northwest of Claremont all draw the major part of their waters from the run-off of the San Antonio basin and the much smaller and less important basins of Thompson and Liveoak creeks. Their situation, which has been determined as

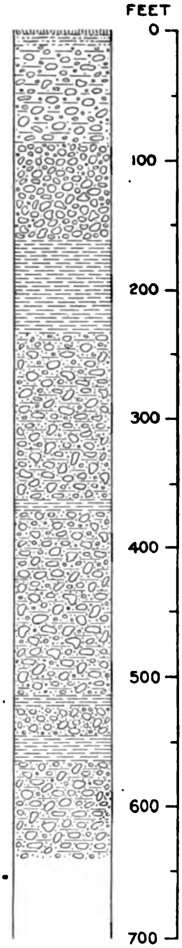


FIG. 6.—Section of San Antonio Water Company's well (No. 73, Cucamonga quadrangle).

most favorable by years of work in development, is in the belt through which practically all San Antonio waters must percolate. The peculiar position of the old Palomares ciénaga, on the high ground at the eastern point of the San Jose Hills and apparently not in the direct line of run-off from any of the important canyons, together with the abundant water supply which it has always yielded, makes it of especial interest. Practically all of the surface discharge of San Antonio Canyon now passes east of Claremont, and the run-off from the next large canyon to the west—San Dimas—is entirely westward toward the San Gabriel. The Palomares ciénaga is nearly on the divide between them. Apparently the only element in its situation favorable to the formation of an artesian basin is the barrier of the San Jose Hills back of it. Surface conditions alone would lead the student of the ground-water supply to expect the greater part of the San Antonio percolation to be well east of Claremont, but development proves that it is practically all west of a line which crosses the Santa Fe Railway about 1 mile east of the town.

The true explanation of this diversion of the San Antonio percolating waters westward against the foot of the San Jose Hills, when their normal course apparently should be directly southward from the mouth of the canyon, is to be sought in the buried older topography (fig. 7), which has been discussed in part in the consideration of the Red Hills waters. The evidence furnished by well records, which is rather scant, and by water levels, also scant but yet more complete than the other, indicates that a barrier (a so-called "dike"), which is probably only a buried hill of the older alluvium, extends from the base of the spur east of the mouth of San Antonio Canyon southward and slightly westward in a gentle curve toward the south line of the Palomares ciénaga and the east point of the San Jose Hills. West of this curved line lie the producing wells of the district, with a water plane high enough, except at some points near the base of the mountains, so that the waters may be pumped

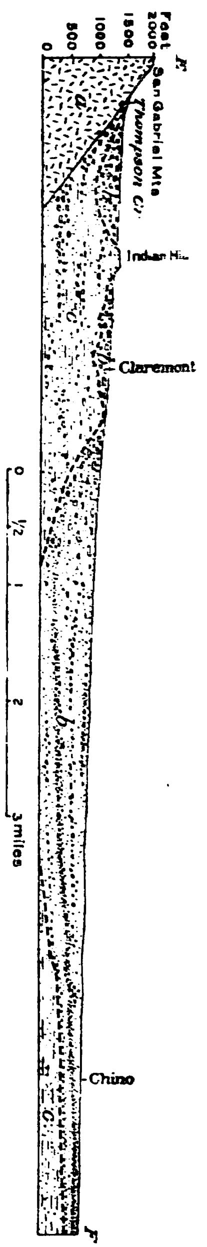


Fig. 7.—Diagrammatic section from the base of the San Gabriel Range through Indian Hill, Claremont, and Chino; a—granitic rocks; b, c—earlier and later alluvium and hypothetical boundary between them.

readily; east of it are many dry shafts, or if water is encountered it is at a much greater depth than across this line. Underground waters from the Cucamonga Canyon are checked and held up so that they are accessible by the Red Hills and by buried northwest and northeast extensions of them, while the same effect is produced on the San Antonio Canyon waters by the buried ridge indicated above.

Between these two valuable water-bearing districts is an irregularly triangular area, with its axis perhaps a quarter or a half mile west of San Antonio avenue and its base extending along the Santa Fe tracks, in which ground waters are found only at depths too great for profitable development at present. This is presumably a valley in the earlier buried "Red Hills" topography, and the underground waters entering it across the buried ridges or "dikes" to the northeast and northwest sink at once to lower levels, much as surface waters are found at lower levels below a dam than above it.

The first waters taken from the old Palomares ciénaga (Pl. I, *C-D* and fig. 8) were waters which rose naturally under artesian pressure and supplied San Jose Creek. These waters were diverted into a ditch and used for irrigation as early as 1840. The use was not extensive, however, until the seventies, when the available amount was increased by developments consisting of drainage ditches cut into the ciénaga and of artesian wells. These wells continued to yield a supply until near the end of the decade between 1890 and 1900, when they gradually failed as a result of increased development and drought. Now all waters drawn from this original artesian basin are pumped. The smaller Del Monte and Martin marshes have had similar histories. They first yielded spring waters; then with the "development" of the water-bearing lands, short-lived artesian wells were procured and the springs dried out. Now all water used is pumped.

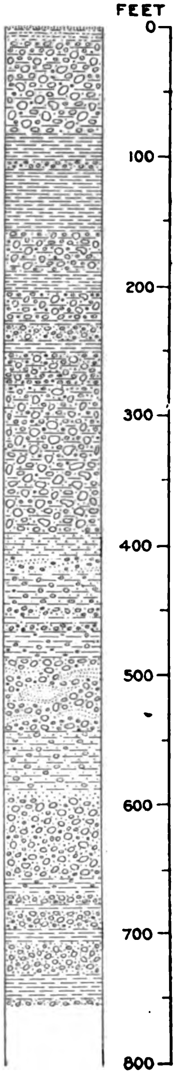


FIG. 8.—Section of Gird well No. 6, Palomares ciénaga (near No. 284, Cucamonga quadrangle).

CHINO ARTESIAN BELT.

All the waters which escape underground from the higher water-bearing lands to the north, all the return irrigation waters from the extensive irrigated areas about Pomona, Claremont, Ontario, and

Cucamonga, and the winter flood waters from the mountain canyons between Lordsburg and Etiwanda which are absorbed south of a line connecting the eastern part of the San Jose Hills and the Red Hills, percolate slowly southward toward Santa Ana River, the main drainage line of this part of the State.

In the vicinity of Chino and for 5 or 6 miles southeast of that town these ground waters are under sufficient pressure to rise to the surface when wells are drilled in the water-bearing sands. The area within which these rising waters are known to occur covered about 21.4 square miles in 1904. This represents a slight shrinkage from the maximum original area of approximately 23 square miles, when the basin was entirely undeveloped and rainfall in this part of the State was heavy. The southwestern rim of the basin is formed by the bed rock of the Puente Hills. Toward the northeast it is indefinitely limited by the rising ground of the Cucamonga Plains. Its southern edge, so far as it is revealed by development, is a rather difinite line that is probably determined by the shoaling of the basin in this direction, through the rise of its relatively impervious base toward the surface. This base seems to consist of an older gravelly alluvium, like the coarser phase of the Red Hills beds, but beneath this Tertiary sandstones and shales or granitic rocks such as outcrop near Corona would doubtless be encountered in sufficiently deep drilling.

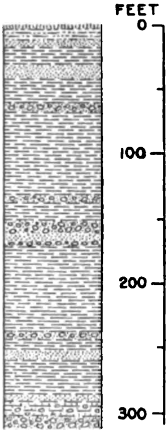


FIG. 9.—Section of W. P. Brown's well (No. 221, Cucamonga quadrangle).

Throughout this belt, as in most of the artesian districts, there are moist lands and springs that mark the points at which the waters under pressure below leak to the surface. Chino Creek and other small streams which drain the area do not show the usual shrinkage of southern California streams during the last decade, but on the contrary have maintained their flow or have increased it slightly. Santa Ana River at the narrows below Rincon has increased in flow from a minimum of 14 or 15 second-feet in 1888 to a minimum of 60 or 70 second-feet in 1904. This increase is accepted as one of the striking examples of the effect of return irrigation waters in adding to the volume of flowing waters below the irrigated lands during a dry period. Much of this increase is no doubt due to irrigation in the vicinity of Riverside, but an important proportion is also to be attributed to the steady application of water to the land in the colonies along the western margin of the Cucamonga Plains. A large part of this latter return water passes through the Chino artesian belt in its slow percolation seaward, and helps to account for the fact that this basin has exhibited less shrinkage during the trying years of drought which have just passed than other important artesian basins of this end of the State. It is also true that this basin has been less vigorously developed than others, chiefly because there has been difficulty in securing good titles to land on the old Chino rancho until recently. These two conditions, then, moderate development and favorable situation in relation to return irrigation waters, account for the fact that this basin is now in excellent condition so far as its water supply is concerned.

The Chino basin proper has not been explored to great depths by the driller, the deepest well being that belonging to Edward Lester (No. 36, Cucamonga quadrangle). It is 467 feet deep, and all the coarser strata are found above 390 feet. Most other wells within the basin are 300 feet or less in depth. (See fig. 9.)

The deepest well in the Cucamonga Plains, the Lorbeer well (fig. 10), just northwest of Chino, was drilled to a depth of 973 feet, but the record indicates that below 500 feet the drill pierced the older alluvium, consisting of red clays and cemented beds which yielded no water. Southwest of Chino, toward Santa Ana River, there are outcrops of slightly hardened gravel which seem to belong to the earlier alluvium. These scattered facts suggest that the filling of modern wash within the Chino district is a comparatively thin veneer, 500 feet or less in thickness, beneath which lie relatively compact older clays and cemented gravels which are dry or but meagerly water bearing. If this inference is correct, the value of wells drilled in this region in the future will not be increased by extending them in depth beyond 300 to 500 feet. The data are too incomplete as yet to state this as more than a probable condition. A few deep test wells drilled in the area extending 4 or 5 miles southeastward from Chino will give much needed light on the underground conditions.

The apparent shallowness of this basin, taken in connection with the rather irregular topography along its southern border in the vicinity of Saant Ana River, leads to the belief that its limits in this direction are due to the rise toward the surface of

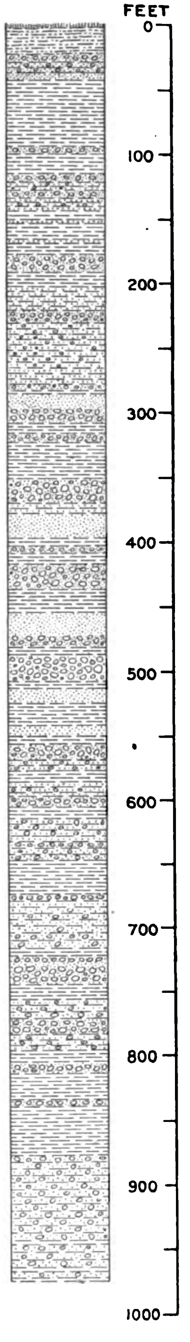


FIG. 10.—Section of Lorbeer well (No. 154, Cucamonga quadrangle).

the dry older alluvium which forms the floor of the basin farther north.

SAN JOSE VALLEY.

The Puente and San Jose hills, which together constitute the northwestern extension of the Santa Ana Mountains, are separated by the valley of San Jose Creek. This stream is peculiar in that it rises not in the hills themselves but in the western edge of the Cucamonga Plains, whence it flows directly across the hill area through a restricted valley into the San Gabriel basin. It is believed to be a compound stream, resulting from a reversal of drainage caused by the growth of the San Antonio alluvial fan. The original divide between the eastward-flowing and westward-flowing elements of this compound stream seems to have been about 2 miles below Spadra. At that time the east end of San Jose Valley drained into the Santa Ana, and the west end drained as now toward the San Gabriel. With the growth of the San Antonio fan southward the original eastern outlet was blocked, slowly filled, and finally given a westward slope. The Palomares ciénaga probably originated with this growth of alluvial deposits and its excess waters became the source and principal feeder of San Jose Creek. Now, when there is a surface flow in this creek, its waters rise on the north slope of the eastern point of the San Jose Hills, flow westward around the point of the hills, and double back into the San Jose Valley, giving a very tortuous alignment to the upper portion of the stream.

The sand and gravel filling in the eastern portion of the San Jose Valley in the vicinity of Pomona is rather deep; wells have been drilled here to depths between 300 and 400 feet without reaching bed rock. Near Spadra are wells between 150 and 300 feet deep which do not reach the rock bottom of the valley, but others much shallower near the borders of the area encounter rim rock, the "hill formation," as it is locally called. In the vicinity of Lemon bed rock seems to be near the surface of the valley. In the Howell well and tunnel the hill shales are found at a depth of 35 feet, but the McClintock, Lee & St. Clair well, 1 mile farther south, failed to reach rock at 100 feet. From this neighborhood westward the valley presumably deepens gradually until it unites with the main San Gabriel basin below Puente. Its underground water supply, while replenished in part, of course, by local run-off from the surrounding hills, has been fed in the past to an important extent by the excess from the Palomares ciénaga, which San Jose Creek drains, and that supply has, with but little question, been adversely affected by the extensive drafts on this ciénaga for irrigation about Pomona.

SAN DIMAS DISTRICT.

DEVELOPMENT.

West of the Cucamonga Plains and between the San Jose Hills and the base of the San Gabriel Range is an area, extending westward to San Gabriel Wash, which has been growing steadily in importance in recent years as a productive citrus district. It includes the towns of San Dimas, Covina, Glendora, and Azusa, with their surrounding tributary horticultural belts.

The preservation of the citrus acreage planted previous to 1897 and its extension since have been accomplished here, as in most of the orange-growing sections of the south end of the State, by the development of underground waters. To bring about this result many important wells have been put down during the last decade. This development has been particularly extensive in San Dimas Wash because valuable lands about Glendora and Covina could be conveniently served by these waters, and on the mesa lands about Laverne because this region is especially adapted to citrus culture and is not served by gravity waters from either the San Gabriel or the San Antonio system. The flowing waters from the smaller canyons between these two streams are of course utilized, but the flow from them ceases or seriously diminishes during the heated term, and must be augmented by ground waters to provide for the continuous irrigation which citrus fruits require. This development has resulted in the accumulation of a considerable mass of evidence on underground conditions, and inasmuch as a large acreage is dependent on waters obtained by pumping, great interest is felt by the dependent communities in the conditions which the developments reveal.

SURFACE CONDITIONS.

The red mesa lands, which represent the older topography of the Indian Hill and Red Hills type, are widely distributed in this narrowest part of the valley between the San Jose Hills and the San Gabriel Mountains. They form the mesas on either side of San Dimas Wash, which is, indeed, a canyon cut in this older alluvium and then partially refilled by the modern stream débris; they extend from San Dimas eastward beyond the mouth of Liveoak Canyon and southward toward Laverne and Lordsburg. In the latter direction their surface extent can not be determined with accuracy because they are mantled by the later alluvium, and the soils derived from the two formations are very commonly so much alike that they can not be distinguished. The obscurity is increased where the older mesa formation is coarse and gravelly, as it is in numerous places near the mountains. In many such places its red color is wanting and it is to be distinguished from the latest wash only by its distribution and by a slight induration, which although very imperfect is usually somewhat greater than that of the later gravels. North of San Dimas Wash a bench of the red clays, in many of the exposures very typically developed, extends eastward from the point of the hill south of Glendora to the base of the main range. Between Azusa and Glendora a fringe of this formation flanks the mountain base. In these described areas it forms the actual surface; over other sections it is probably not deeply buried. For example, it presumably underlies the entire area about the head of Walnut Creek, extending from Laverne, San Dimas, and the country to the west, southward to the San Jose Hills, and it may underlie much of the Glendora district at slight depths. It should be understood clearly that these red clays and gravels were distributed just as the clays, gravels, and sands are being distributed to-day over their channels by the San Gabriel and other streams. In both cases the material laid down is simply the ground-up rock brought by the streams from their mountain canyons, and the total quantity of earlier and later wash is equal to the amount removed by the streams in cutting the canyons.

The important facts about the older alluvium are that in certain areas it has been uplifted since its deposition and that time enough has elapsed to permit it to be eroded by the streams since its uplift, so that an irregular topography has been produced in it. There are hills here and valleys there, canyons in one area, mesas in another, and these have all been smoothed over and partially buried by the modern stream wash. We do not know this older topography, therefore, in detail. We see only here and there a hilltop or a broad mesa standing above the modern wash. The rest of the red alluvial hills and valleys are buried beneath it. In many areas, however, they manifest themselves distinctly in the influence that they exert on the circulation of the ground waters. While this influence is marked, it is not everywhere complete, because the old alluvium is not impervious. A ridge of it buried in the later alluvium may therefore not entirely deflect the waters percolating through the latter, although the difference in porosity is in many places great enough to make the deflection nearly complete.

Both the older and the younger alluvial deposits exhibit the irregularity which is characteristic of the alluvium everywhere. Both have their coarse and their fine phases, their pervious and their impervious lenses and strata. This fact increases the difficulty of distinguishing between them, because though, taken all in all, the modern wash is more open and permits of freer circulation of ground waters than the older wash, yet many of the better beds in the older wash may be superior to the poorer beds in the modern wash in this important respect. Both are water bearing, and under favorable conditions good wells are procured in each, but the greater number of better wells are drilled in the modern gray wash, and in many places the older alluvium is dry.

UNDERGROUND CONDITIONS.

The extensive developments about Lordsburg and Laverne and in San Dimas Wash have brought to light certain important phases of the underground conditions. Bed rock has been found in enough of these wells to give a hint as to the depth of the alluvial filling and the downward limits of water-bearing gravel. A well which has been mentioned before, belonging to the Irrigation Company of Pomona (No. 182, Pomona quadrangle), enters bed rock at a depth of about 800 feet; that is, at 160 feet above sea level.

In one of the Covina Irrigating Company's wells south of Lordsburg the drill entered lava, similar to that which outcrops in the hills farther to the south, at 244 feet from the surface, although other wells of this group which were drilled 150 feet deeper are in alluvium to the bottom.

In the recently drilled Peyton well (No. 247, Pomona quadrangle; see fig. 11) a granite bed rock, first encountered at 538 feet from the surface, was penetrated for nearly 100 feet. Bed rock here stands at something more than 600 feet above sea level and in the Covina well at about 750 feet.

The San Dimas Irrigating Company's wells on the site of the old "Mud Springs" ciénaga reached a shale bed rock at about 200 feet below the surface; that is, at about 800 feet above sea level. These and the Covina wells are near the south rim of the valley.

At the bottom of wells Nos. 208 and 210, owned by Baker & Son and by N. L. Sparks, a lava bed rock was found at 330 and 300 feet, respectively, below the surface; that is, at a little less than 900 feet above sea level. North and south of San Dimas Wash are bed-rock hills of shale, sandstone, and lava, and wells drilled near these knobs strike the same rock formation at slight depth. The Deacon wells, belonging to the Covina Irrigating Company, are of this type. Of the wells mentioned none are in the center of the valley, where bed rock is probably deepest, although the Peyton well, north of Lordsburg, is not far from the center. A number of the San Dimas Wash wells are more than 500 feet in depth (fig. 12), and so far as reported, in no well except those of the Deacon

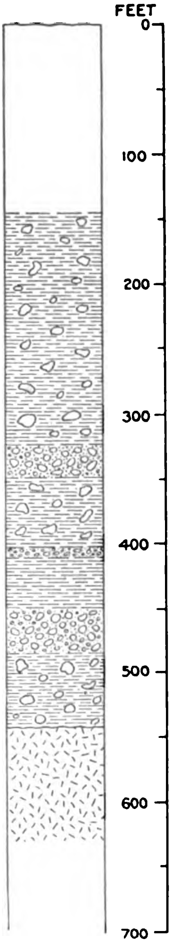


FIG. 11.—Section of Peyton well (No. 247, Pomona quadrangle).

group, drilled near the base of a bed-rock mound, was rock found in place. It seems unlikely, however, that bed rock is more than 1,000 feet below the surface in this vicinity. The buried bed-rock surface, it is to be remembered, is probably quite as irregular as that part of it which lies above the alluvial filling. It consists of ridges, knobs, and valleys, so that the depth to it will not be uniform and can not be predicted with exactness at any point. The records of the wells which have been mentioned support the opinion that would be formed by a mere inspection of the topography, namely, that bed rock lies closer to the surface in this narrow belt, where the Coast Range approaches nearest to the base of the San Gabriel Mountains, than in the broader San Gabriel Valley to the west or in the wide Cucamonga Plains to the east.

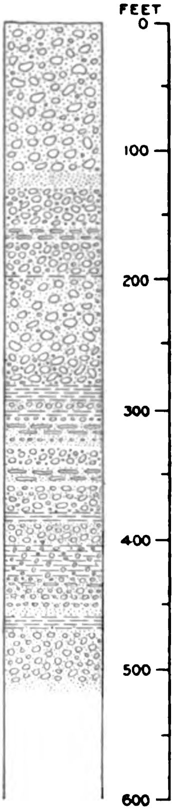


FIG. 12.—Section of Western Water and Power Company's well (No. 233, Pomona quadrangle).

The greater part of the sands, gravels, and clays in the San Dimas area belongs, as has already been indicated, to the older alluvium, the "Red Hills formation," as it is locally called; but in San Dimas Wash itself a fairly deep canyon has been cut into this older wash and then partially filled again by the loose sands and gravels brought out by the stream (fig. 13). The walls of the unfilled portion of this older canyon limit the mesa north of San Dimas and Laverne.

The depth of the loose modern filling in the wash seems to be only about 100 or 200 feet. Below that depth some of the wells encounter red clays which presumably belong to the older alluvium that forms the walls of San Dimas Wash.

The depth to bed rock in the wash is of interest to irrigators because it determines the final lower limit from which irrigating waters can be drawn. None of the owners who have put down wells near the middle of the wash, where the freest water-bearing gravels are found, have reported bed rock, although it has been reached in a number of the wells near the southern edge. In view of the restricted character of the middle valley of the San Dimas and the fact that it is only about 1 mile from rim rock on the south of the wash to rim rock on the north, near the town of San Dimas, it is manifest that bed rock can not lie at great depth below this part of the stream bed.

North of Laverne the valley is broader and may be deeper, since its bottom is probably irregular, but the greatest depth to bed rock here is probably beneath the mesa in the old alluvium, while the principal producing wells lie in the wash within less than three-fourths of a mile from the northern rocky border of the valley. If the general average slope of this mountain rim, a slope of 1,000 to 1,500 feet per mile, is maintained beneath the wash, as it probably is, then bed rock is to be expected at less, probably at considerably less, than 1,000 feet from the surface in that part of the wash where development is most intense.

The great value of the gravels which have been pierced here is due to their coarseness, openness, and looseness, and the consequent freedom with which they yield the water that they contain, and the readiness with which they are recharged after having been heavily pumped.

The San Dimas area forms the extreme eastern extension of the San Gabriel Valley, but has been discussed as a separate district because of the intensity and importance of its development, and because, as it stands near the divide between the San Gabriel Valley and the Cucamonga Plains, underground conditions are unlike those in either of the latter areas.

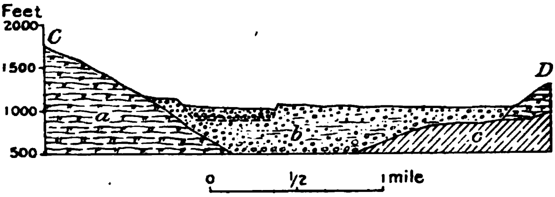


FIG. 13.—Diagrammatic section across San Dimas Wash; *a*, lava; *b*, alluvium; *c*, shale.

SAN GABRIEL VALLEY.

Westward from San Dimas the valley of San Dimas Creek gradually opens out into the San Gabriel Valley proper, which extends as a wide plain with a gentle slope toward the south to the San Rafael Hills beyond Pasadena. San Gabriel River at the mouth of its canyon discharges upon this plain and leaves it through the Paso de Bartolo, a dozen miles to the southwest. Throughout much of the year its channel across the plain is a dry wash, but during the period of the winter rains a surface stream often extends entirely across the valley. At other seasons the water which reaches the inner edge of the plain from the canyon sinks and crosses the valley by percolation underground. Water always rises in and near the Paso de Bartolo in springs, which feed Rio Hondo and the San Gabriel and thus supply the canals which head here with irrigating water. So far as known, this central portion of the basin is a simple broad valley of deformation, whose bed-rock bottom may be several thousand feet below the surface.

That part of the San Gabriel Valley, however, which lies north and west of a line connecting South Pasadena with the spur of the San Gabriel Mountains between Santa Anita Canyon and Monrovia, is a distinct province so far as its underground waters are concerned. A fold in the late strata which form the valley filling, a fold which in places expresses itself topographically as a ridge or a series of knobs, here forms an effective underground barrier to the waters that are percolating toward the axis of the valley from the northwest, and so makes of this northwestern tract a distinct area, which will be spoken of as the Pasadena Basin.

In the central part of the San Gabriel Valley development has not as yet been very intense. The cultivable lands along the northern edge, particularly those east of San Gabriel Canyon, are irrigated largely by canals which take gravity water from the canyon. There are a number of successful wells west of the wash close to the foothills, where soils are good, but farther south is a wide area of rough land which has little agricultural value and beneath which the water plane lies at considerable depths. Still farther south, toward Bassett and Elmonte, the soils are finer and more productive, and the water plane lies nearer the surface, so that the development of underground waters is less expensive. In this area they are more generally used. The Paso de Bartolo is the water gap through which the San Gabriel Valley waters are discharged upon the coastal plain. It is less than 2 miles wide, and its depth is not known, although the topography and the records of wells drilled in the pass indicate clearly that the depth must be considerable, perhaps 600 or 800 feet. The valley to the north is doubtless much deeper than this, and the rise of the ground waters in the pass is due to a combined lateral contraction and shoaling of the basin, so that the cross-section of the field through which the waters are percolating is very much lessened, and they are forced out as surface flows. The waters which accumulate here above the pass and escape through it, either over the surface or beneath it, include all the waters that drain into the San Gabriel Valley from San Dimas westward to Pasadena, except those that evaporate from the water or soil surfaces. The greater portion of the subsurface circulation of even Arroyo Seco probably escapes to the coastal plain by this route, although its surface waters join the Los Angeles River system at Los Angeles.

The greater San Gabriel basin, in which the absorptive gravels occur, is a constructional valley of the type almost universal in southern California. It is one of the more extensive of the basins of this type, and its dimensions are difficult to estimate. Wells are not numerous except near the southern margin, and these are generally of depths so moderate that they give no clue to the position of the bottom of the basin. One exception is to be noted. The test well of the East Whittier Land and Water Company, just west of San Gabriel Wash and north of the Southern Pacific tracks, has been extended to a depth of 1,260 feet. Throughout this distance the drill penetrated only alternating sand, gravel, and clay strata. The coarsest beds were found between 70 and 350 and between 570 and 780 feet from the surface. Below 780 feet coarse strata are unusual and clay predominates, but the bottom of the well is in unconsolidated material, bed rock not having been reached.

Wells 300 feet deep in the narrowest part of the Paso de Bartolo likewise failed to reach bottom, so that this outlet of the San Gabriel Basin has been depressed since it was cut by the stream until it stands below sea level. Just below and west of the pass, on the inner slope of the coastal plain, is a 500-foot well which penetrates alluvium throughout.

At Elmonte a well belonging to the Southern Pacific Company is 480 feet deep, and of course is in alluvium to the bottom. Other wells from 300 to 500 feet deep in the vicinity of San Gabriel and Savannah record the same conditions.

East of the San Gabriel and 3 miles north of Puente is a well belonging to Edward Fickewirth which is 850 feet deep (fig. 14). The record shows only an alternation of sand, clay, and gravel strata, but some of the gravel is reported to be cemented and may belong to the Pliocene rocks, which outcrop in the Puente Hills only a mile away. Shallower wells near this one are reported to yield more freely. In general the developments have furnished no evidence which will permit a direct estimate of the position and character of the rock floor of the San Gabriel Valley. It certainly lies well below sea level, not less than 1,000 feet below at the East Whittier pumping station, where the land surface has an elevation of about 300 feet. Without exploration to it, statements as to its position can have little value. The basin is too broad and irregular in outline to make projection of the slopes of the bordering hills a safe guide to the position of bed rock beneath the surface, and the existence of a fault or fault zone of great magnitude along the northern border adds to the uncertainty of the bed-rock position in this direction. It is highly probable that the depression of valleys of this type has been gradual, and that the filling by unconsolidated materials has also been gradual, since it has, no doubt, accompanied the depression and has probably kept pace with it. The more deeply buried sands and gravels are therefore the older, and their consolidation is likely to be more thorough. It is quite possible that alluvial sedimentation of this type began toward the end of the Tertiary period, which is represented in the folded conglomerates, shales, sands, and clays in the Puente Hills, and that it has continued with more or less regularity since. If this is true, bed rock beneath parts of the valley, at least, will not be a distinct and easily recognizable feature.

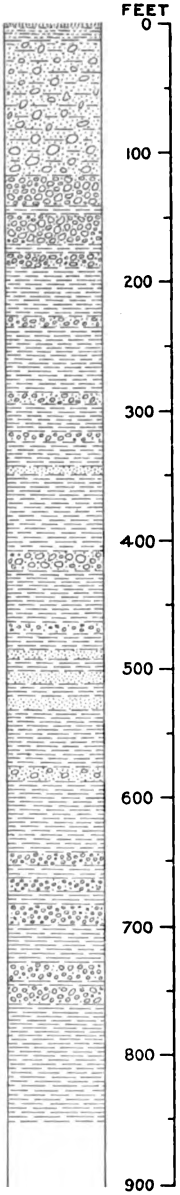


FIG. 14.—Section of Fickewirth well (No. 80, Pomona quadrangle).

Instead, in deep drilling, the late alluvium would gradually become more compact with depth until it passed by imperceptible gradations into bed rock of the type which outcrops in the Puente Hills.

Wherever granitic islands stood up from the deeper-lying granitic basement, however, and were finally engulfed only in the latest accumulations of alluvium, they may be encountered by the drill in its explorations, and then a perfectly distinct and definite bed rock will be recognized. Such a granitic island which projects above the present surface is to be found in Monk Hill, Pasadena, and others which lie beneath this surface are more likely to be encountered in drilling near the northern and western than near the southern and eastern edges of the basin.

PASADENA BASIN.

The Raymond Hotel stands on the crest of a hill near the southern edge of Pasadena. The axis of this hill is an overturned anticline of Miocene sandstones and shales. (See fig. 16.) North of east from the hotel are a series of low knobs and abrupt changes in the valley slope, which extend toward the spur of the San Gabriel Range that lies just east of the mouth of Santa Anita Canyon. At some points along this line the knobs and the steepening slope which are the surface evidences of certain significant underground conditions are conspicuous. At other points they are insignificant, but even here the topography is usually uneven and the zone along the upper edge of the "dike" is marked by dark peaty soil.

The behavior of the underground waters which are seeking an outlet by percolation southeastward from the Pasadena Basin toward the main San Gabriel Valley is even more significant of underground conditions along this line. Above it ground waters lie near to the surface or flow out over the surface in certain places. Below it they lie more than 100 feet lower. The condition is similar to that above and below a surface dam, the water level being much higher above than below because of the impermeable barrier between. Over the face of this subterranean dam, the Raymond Hill dike, the ground-water level has a steep grade, as surface waters have a steep fall over the crest of a surface dam. Above the dike percolating waters are checked in their southward movement and accumulate under pressure where proper physical conditions exist, so that they are artesian.

The greater number of the wells of the Pasadena Basin are located along a zone just above this dike, for the waters here are much more accessible than elsewhere in the basin. A few important wells, all of which, however, involve high lifts, have been installed in a subdivision of the main Pasadena Basin, near its northern edge, which may be spoken of as the North Pasadena Basin. Among these are wells belonging to some of the Pasadena water companies in the neighborhood of Las Casetas and Marengo.

On the mesa just northwest of Devils Gate one of the Pasadena Lake Vineyard Land and Water Company's wells (No. 434, Pasadena quadrangle) is 614 feet deep and does not reach bed rock, although rock outcrops in Arroyo Seco, only a mile away. This illustrates the steepness of the buried bed-rock slopes in this part of the Pasadena Basin. They are probably comparable in steepness with the mountain slopes to the north of the valley. The record of this well indicates a very common succession of sand, gravel, clay, and bowlders to 560 feet. Below that point the proportion of what the driller calls "rock," a term which he generally applies to very coarse material, increases and continues to the bottom of the boring. It seems unlikely that bed rock lies at a great distance below the bottom of this well.

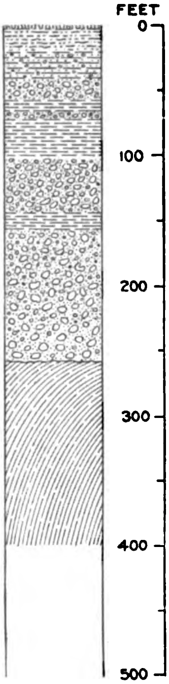
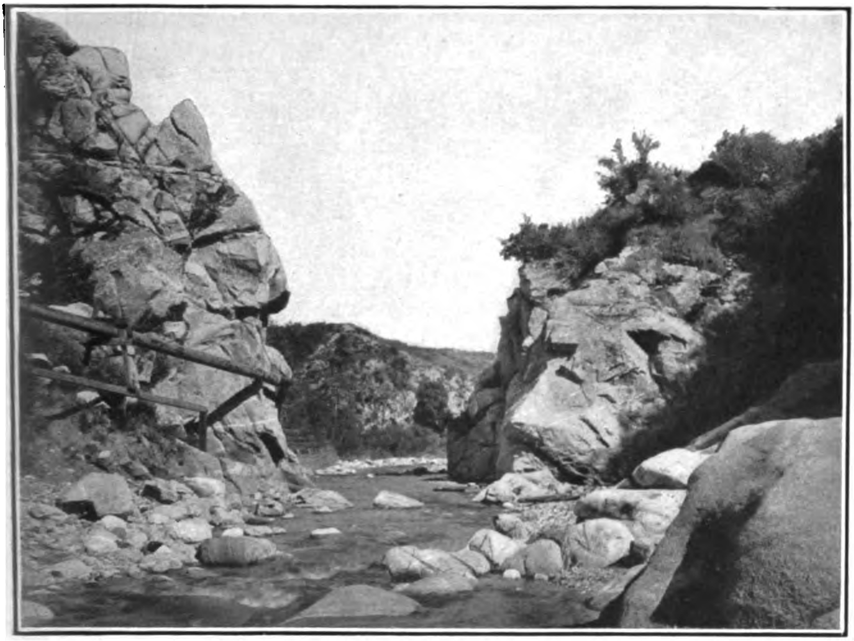


FIG. 15.—Section of Graves & Bean well (No. 449, Pasadena quadrangle).

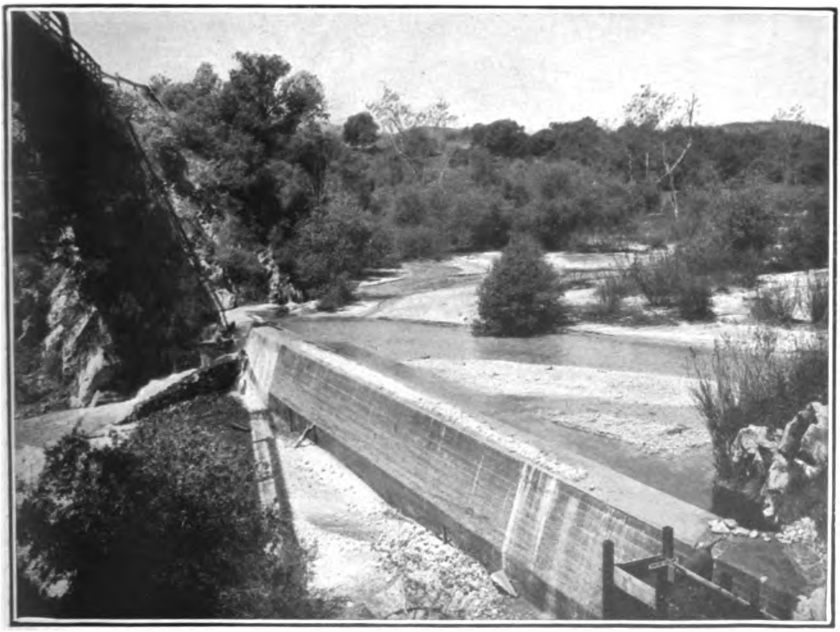
Monk Hill (fig. 16), in North Pasadena, is a bed-rock outcrop which is clearly a southeastward continuation of the spur of the San Rafael Hills through which Arroyo Seco has cut at Devils Gate. This partially buried ridge is thus an eastward extension of the south wall of La Cañada Valley. Its presence is clearly indicated not only by the accumulated underground waters north of it which have been utilized with such success in the Devils Gate developments of the Pasadena companies and the wells about Las Casetas station, and by the much greater depth (200 feet or more) at which waters are found below it, but also by the records of wells Nos. 74 and 74a, which are reported to have reached bed rock at 135 and 146 feet, respectively, from the surface. These wells lie between Monk Hill and the granitic outcrops in Arroyo Seco below Devils Gate (Pl. II, A) and furnish practically conclusive evidence that a continuous bed-rock ridge lies buried under the alluvium between these two points. The effect of this barrier is to check the southward movement of the underground waters which accumulate above Devils Gate, and to force them to make a long detour to the eastward around Monk Hill before continuing southward. They are thus thrown into the San Gabriel drainage basin instead of being tributary to that of Los Angeles River as are the flood waters of Arroyo Seco. An underground barrier thus changes entirely the route followed by the underground circulation of the upper course of the stream, and we have the interesting spectacle of the surface flood waters of a drainage basin flowing seaward by way of one river system, and the underground waters seeking the same destination by another route.

Before the Devils Gate developments were undertaken, some of the surplus underground waters which were held behind this Monk Hill barrier rose to the surface at Devils Gate in the series of springs which formed one of the important original sources of Pasadena water. This surplus is now taken out by the tunnels and wells and the springs have ceased to flow. It is safe to say also that more water may be continuously developed by this system than the springs originally yielded, because much was lost by evaporation in the moist lands about the springs under the original conditions, and also because a part of the surplus which originally no doubt found its way eastward around Monk Hill is probably now brought out by way of the tunnels and wells. At the Sheep Corral springs, as at Devils Gate, Arroyo Seco cuts through a spur of the San Rafael Hills so that its canyon becomes narrow, with rock walls and bottom impermeable to percolating waters. These waters are thus forced to the surface—or were before they were intercepted by development work—and appeared as springs. The situation is less favorable here than at Devils Gate because the Monk Hill bed-rock ridge deflects much of the ground waters eastward away from Sheep Corral, and it is probable that the developments there are supplied in an important measure, perhaps almost entirely, by those Arroyo Seco flood waters which are absorbed in the wide part of the arroyo which lies between Devils Gate and Sheep Corral. At both points submerged dams have been built to bed rock across the narrow part of the arroyo to hold back the underground waters or to force them to the surface. (Pl. II, *B*.)

One of the group of four wells belonging to the East Pasadena Land and Water Company on Franklin avenue and California street is 736 feet deep, its bottom being almost at sea level. It is nearly a mile north of the dike and in its record there is no trace either of the sandstone which underlies Raymond Hill or of the crystalline



A. DEVILS GATE.



B. SUBMERGED DAM ABOVE DEVILS GATE.

rocks which appear in the vicinity of the Sheep Corral springs. Sand, clay, and gravel, such as constitute the general basin filling, are reported clear to the bottom of the boring.

The deepest well reported in the Pasadena neighborhood is one drilled on the Hurlburt place near the south end of the city, just east of Orange Grove avenue. The depth given is 1,300 feet, and it is stated that much of this distance was bored through "granite." Details are not available, however, and as the well is near the western border of the basin, where bed rock is to be expected at comparatively shallow depths, it has no especial significance. A few of the wells drilled near Raymond Hill, as for instance No. 53, belonging to the Euclid Avenue Water Company; No. 448, belonging to the Pasadena Land and Water Company, and No. 449, of the Graves & Bean system, reach the shale or sandstone which appears at the surface about Raymond Hill, but is buried farther east. Other wells drilled farther east along the dike, while numerous, are usually shallow, do not reveal the existence of bed rock, and throw comparatively little light on underground conditions. If the consolidated sandstone and shale beds continue to form the core of the dike in this direction, they lie deeper than the drill has yet reached. But the dike is none the less efficient as a dam, and even in those areas where the only surface outcrops are unconsolidated gravels a comparison of the water levels above and below its line indicates that clays or other impervious materials must form its axis. Folds of this character in beds which are very recent are not at all unusual in this part of the State, and they have an important and significant relation to several of the most prominent artesian areas. The San Bernardino artesian belt, for example, is limited on the downstream side by the Bunker Hill "dike," an anticline in late clays very similar to that which extends eastward from Raymond Hill. The great coastal-plain basin also is limited on its seaward side by a broad broken ridge, which is the surface expression of a gentle arch in the coastal-plain sediments.

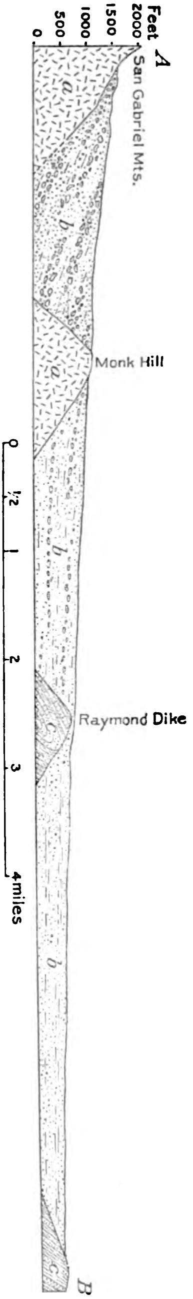


Fig. 16.—Diagrammatic section across San Gabriel Valley from Millard Canyon through Monk Hill and Oak Knoll: *a*, granitic rocks; *b*, alluvium; *c*, sandstone and shale.

All these gentle anticlines are very late features, geologically, and are most important factors in the storage and development of California ground waters.

FLUCTUATIONS IN GROUND-WATER LEVELS.

EVIDENT EFFECTS.

It is probable that ground-water levels in the basins of southern California were highest in the early nineties, at the end of the decade of heavy rainfall which included the exceptional seasons of 1883–84, 1885–86, 1889–90, and 1892–93. The recurring wet winters of this period and the fact that at that time comparatively little development of underground waters had been undertaken, so that there was practically no artificial drainage, were favorable conditions for raising the saturation level of the sands and gravels.

The southern California artesian areas occur in the subterranean basins wherever a favorable alternation of coarse and fine material, a sufficient water supply, and a barrier against which the waters can accumulate are found together. These favoring circumstances are to be sought along the lower edge of the various basins, nearly all of which contain areas that yield such flowing waters. The greatest combined area of the artesian water-bearing lands in southern California was 375 square miles, and while a very definite date can not be fixed for this maximum, it probably occurred in the early nineties. By 1904 there had been a contraction of one-third—to 250 square miles. Much of this contraction was due to the lessened rainfall of the last six or seven years of the nineties, but inasmuch as, in some of the basins at least, shrinkage continued during the four years following 1900, when the rainfall throughout southern California was about equal to the average, this shrinkage must be attributed in part to drainage of the reservoirs by pumping plants and artesian wells.

Ground-water levels in the various basins offer better evidence than changes in artesian areas as to the effect of drought and development on the level of the plane of saturation. For certain areas outside of the foothill belt such evidence of this character as is available has been discussed in preceding reports.[a] It may be stated here, however, that records kept by Mr. Neff, near Anaheim, indicate that in that particular region the underground waters are being drawn out by the numerous pumping plants more rapidly than they are restored by natural processes during years of more than average rainfall. A similar conclusion is forced on the student of conditions in the San Bernardino Valley, where the artesian basin is smaller and somewhat more complete records are available.[a]

---

[a] Water-Sup. and Irr. Papers Nos. 137, 138, 139, and 142, U. S. Geol. Survey, 1905.

In the foothill belt no long-continued observations of ground-water levels have been made. A series of such observations has been begun by the United States Geological Survey, and in time they will furnish accurate criteria from which to judge the effects of the intensive development which the favorable character of the citrus lands there has induced. As yet no far-reaching conclusions can be drawn from them, but such evidence as they present will be discussed.

Although in this area continuous measurements on ground-water levels are not to be had, certain important facts in the history of the artesian belts are available. In the first place it needs to be reiterated that various parts of the foothill belt constitute separate and independent water basins, and that the fluctuation of the ground-water levels in each of these basins depends on local rainfall or contributing local run-off and local developments, and is not necessarily similar to the fluctuation in an adjacent area. Thus the Cucamonga Plains east of the San Jose Hills are to be regarded as one province, San Dimas Wash as another, the lower San Gabriel basin about Elmonte and Bassett as another, the North Pasadena Basin above Devils Gate as another, and the lower Pasadena Basin above the Raymond Hill "dike" as still another. The developments in some of these basins may affect the supply somewhat in others, but this effect is on the whole slight. For instance, excess waters from both the Pasadena basins and from San Dimas Wash have always drained toward the Elmonte basin, and have made small contributions to the supply there, but inasmuch as far the greater part of this supply comes directly from San Gabriel Canyon, the effect on the Elmonte water levels of developments at Devils Gate or San Dimas is negligible. A more pronounced effect of this sort is to be observed in the result in the San Jose Valley of developments in the old Palomares ciénaga above Pomona. At a time preceding the settlement of the valley San Jose Creek was a summer stream, fed by the waters which rose as springs in this ciénaga. After the settlement these waters were diverted for irrigation, and San Jose Valley was thus deprived of a part of its normal supply. Similarly all developments in the San Dimas pass about Lordsburg probably affect in a small but indeterminable measure the ground-water supply east and west of that locality, in areas toward which these waters would drain if not disturbed. All of these effects are in part, and some, perhaps, are wholly, neutralized by the return waters which seep down from the irrigated lands.

---

[a] Water-Sup. and Irr. Paper No. 142, U. S. Geol. Survey, 1905, pp. 50-67.

The principal original artesian areas of the foothill belt were the Pasadena Basin, a long, narrow area just above the Raymond "dike;" the area 3 miles south of San Gabriel, in which were three or four weak flowing wells; the Palomares ciénaga, above the eastern point of the San Jose Hills; the Del Monte and Martin ciénagas, near Claremont, and the "east" and "west" ciénagas, in the Red Hills. Water rises to the surface naturally in but two of these areas at present; in the others a heavy lift is required to bring it out to the level of the heads of the ditches. The effect of development and drought here is even more pronounced than that observed in the coastal plain or the San Bernardino Valley, where continuous measurements of the decline in ground-water levels indicate that drafts at present are excessive. In the Palomares ciénaga water rose to the surface as late as 1900 in some of the stronger wells, and much artesian water was available there two or three years before this date. In 1905 the ground-water level in the heart of the old area of flow was 35 feet or 40 feet below the surface, and in some of the wells which were once artesian the water stood 60 or 70 feet below the surface. Tunnels at 50 to 100 feet below the surface now tap the waters of the East and West ciénagas in the Red Hills district, and the gravity flow, even at these levels, is small.

MEASUREMENTS.

In order to obtain definite data on these phenomena of changing water levels the United States Geological Survey has selected a number of wells in various localities for regular measurement.

WELLS NEAR POMONA.

In the vicinity of Pomona two wells thus selected belong to the Gird group near the east end of the old Palomares ciénaga. The measurements thus far made are given below.

Measurements of fluctuation of water level in wells near east end of old Palomares ciénaga.

Date.	Depth to water.			
	Well No. 284.		Well No. 299.	
	Ft.	*in.*	*Ft.*	*in.*
1904.				
September 7	75	2	76	2
October 6	75	4½	77	2
November 16	74	6	76	5½
December 13	74	3	76	2½
1905.				
January 11	68	10½	70	5½
February 20	66	1	67	8½
March 10	65	11	67	5½
April 14	63	11	65	7½
May 17	62	11	64	5
June 22	66	8	68	2
July 20	70	10	72	8
1905—Continued.				
August 16	71	11	73	9
September 21	73	5	75	3
November 11	70	4½	71	5
December 20	67		68	8
1906.				
January 26	64	9	68	6
March 14	62	10	67	4
May 8	62	5	62	½
June 26	64	5	65	10
August 1	67		68	1
September 24	67	½	68	3
December 10	64	3½	65	8

These two wells are near together and their measurements are very similar throughout. Each shows a gain between the September measurements of 1904 and 1905, and a more pronounced gain when the water level in September, 1906, is compared with that of September, 1905. The period spanned by the measurements includes only two high-water dates—May, 1905, and May, 1906—and a slight gain is indicated at the later period, the gain being more pronounced in well No. 299 than in its neighbor. Well No. 284 is within 100 feet of one of the Gird wells which flowed until 1896. The sharp rise in the water plane in these wells between the measurements of December, 1904, and January, 1905, is probably to be attributed to the cessation of pumping in the vicinity at this time; and the almost equally sharp fall between the May and June measurements of the following spring marks the vigorous opening of the summer pumping season. If any two dates a year apart are selected in the table, it is seen that the water level has risen by amounts ranging from a few inches to as much as 7 feet in the interval, so that in this part of the basin the heavy rainfall of 1904–5 and 1905–6 has resulted in a marked improvement in conditions. As the water level fell at an average rate of 7 to 8 feet per year during the decade from 1896 to 1906, improvement is welcomed.

A well near the western edge of Pomona, owned by B. Linnastruth (No. 12, Pomona quadrangle), has been measured since December 19, 1904. The results are as follows:

Measurements of fluctuation of water level in Linnastruth well, near Pomona.

Date.	Depth to water.		Date.	Depth to water.	
1904.	*Ft.*	*in.*	1905—Continued.	*Ft.*	*in.*
December 14	90	6½	November 12	93	4
1905.			December 21	93	6
January 12	90	9	1906.		
February 21	91	1	March 15	92	6
April 15	91	5	May 9	94	6
May 17	91	6½	June 27	93	6
June 22	92		August 2	95	6
July 21	92	10½	September 25	96	
September 23	93	6	December 11	95	2

This well is unfavorably situated, in that it lies below the majority of the strong pumping plants of the Pomona neighborhood and away from the storm-water channels, so that it gets the full adverse effect of heavy pumping and but little of the beneficial effect of the flow in the flood channels. The result is that there has been an almost uniform slow decline since the beginning of measurements; the water plane in December, 1906, being 4 feet 7½ inches lower than in December, 1904. During only four of the thirteen intervals between measurements was there any recovery whatever, and the greatest of these, which took place between the May and June measurements, 1906, registers an improvement of only 1 foot.

WELLS NEAR SAN DIMAS.

In the years following 1896 San Dimas Wash attracted attention because of the ease with which water could be developed in it, and because of its elevation, which made it possible to conduct the water by gravity to the citrus lands in the Glendora and Covina neighborhoods. In 1896, when the first plant was installed by J. O. Enell, the ground-water level was within 44 feet of the surface; but with the continued installation of plants and continuous pumping during the dry years the water plane was drawn down to about 135 feet in 1905, and when all the pumping plants are operating, it may be temporarily lowered below 200 feet in this immediate vicinity. Details of this decline are not available. United States Geological Survey measurements have been maintained about two years, and they indicate that during that time there has been a gratifying improvement in conditions in the wash, due directly to the increased rainfall within the San Dimas watershed and the consequent added quantity of water which has been absorbed by the gravels there, and to the increase in gravity waters in other near-by canyons. Since many of the irrigating systems use pumped water only to augment their gravity supply, this increase has greatly reduced the drafts on the San Dimas basin by the pumping plants established there.

One of the wells selected for measurement (No. 246, Pomona quadrangle), belongs to E. Firth, and is situated half a mile west of the principal group of pumping stations and about 50 feet below them. It is far enough away from them not to be greatly affected by the fluctuations due to the starting and stopping of pumps, and so records the general rise and fall of the ground-water level. The record is as follows:

Measurements of fluctuation of water level in Firth well.

Date.	Depth to water.		Date.	Depth to water.	
1904.	*Ft.*	*in.*	1905—Continued.	*Ft.*	*in.*
September 7	110	6½	August 16	105	11
October 7	111	7	September 21	106	7½
November 16	113	2	November 11	108	1½
December 13	113	11	December 20	109	1
1905.			1906.		
January 11	114	8½	January 27	107	[illegible]
February 20	113	11	March 15	108	2
March 11	113	7	May 8	87	10
April 14	106	10	June 26	92	11
May 17	104	9	August 1	[a] 114	5
June 22	104	4	September 24	97	4½
July 20	105	6	December 10	96	11

[a] Pumping.

A comparison of September measurements in this well indicates a gain of 4 feet between 1904 and 1905, and a gain of over 9 feet between 1905 and 1906, or a total of 13 feet for the two years. The lowest period following the summer of 1904, however, was not reached until January, 1905, and that of the succeeding season came in December. A comparison of these two dates indicates a gain of somewhat more than 5½ feet in the interval.

If we accept the September measurements of 1904 and 1906, with their recorded recovery of 13 feet, as indicating fairly the improvement in conditions during these two years of heavy rainfall, and regard the decline between 1896 and 1904 as aggregating about 65 feet, the greater part of which took place in the latter part of the interval, we reach the conclusion that ten years of rainfall as heavy as that of the last two seasons will restore the underground waters to their original level. Even during these two years of heavy rainfall, however, not all wells in the vicinity exhibit so marked a recovery, as is evident from the following record of the Azusa Irrigating Company's well (No. 251, Pomona quadrangle):

Measurements of fluctuations of water level in Azusa Irrigating Company's well.

Date.	Depth to water.		Date.	Depth to water.	
1904.	*Ft.*	*in.*	1905—Continued.	*Ft.*	*in.*
October 7	97	2	September 21	97	4
November 16	97	8	November 11	98	6
December 13	98	11	December 20	99	
1905.			1906.		
January 11	99	1	January 27	97	10
February 20	98	4	March 15	97	2
March 11	97	4	May 8	93	2
April 14	95	6	June 26	91	1½
May 17	94	3	August 1	92	4
June 22	94	1	September 24	98	7½
July 20	95	4	December 10	100	11
August 16	96	4			

This well is about one-half mile southwest of the Firth well, is farther from the storm-water channel and from the big pumping plants, and is consequently expected to exhibit less marked fluctuations. There was but 1 inch difference between the low-water periods following the summers of 1904 and 1905; but the low-water period of 1906 is 1 foot 11 inches below that of the preceding fall. The September measurement in 1906 shows a loss over that of 1905, and the latter a slight loss over the October measurement of 1904. The high-water period of June, 1906, however, shows a recovery of 3 feet as compared with that of June, 1905. There is a slight net loss in the two years of observations, but as measurements are made at considerable intervals, with a resulting improbability that either the highest or the lowest water periods are detected, it may be said in a general way that this well is just about holding its own.

Two other observation wells (Nos. 144 and 149, Pomona quadrangle), belonging respectively to William Ferry and Sidney Deacon and located 1½ to 2 miles southwest of San Dimas, show somewhat different results. Their record is given below.

Measurements of fluctuations of water level in wells near San Dimas.

Date.	Depth to water. Well No. 144.		Depth to water. Well No. 149.	
	Ft.	*in.*	*Ft.*	*in.*
1904.				
October 7	199	8	124	3
November 16	199	10	124	
December 13	199	10½	124	
1905.				
January 11	199	9½	123	6
February 21	199	8	123	5
March 10	199	8½	127	
April 14	200	4	125	8
May 17	....		124	8
June 22	200	4½	125	1½
July 23	200	6	125	5
August 16	200	7	125	5
1905—Continued.				
September 21	200	7	125	7
November 11	201		126	
December 20	201		....	
1906.				
January 27	201	3	124	6
March 15	201	3	124	3
May 8	201	2	....	
June 26	201	5½	124	6
August 2	201	9	....	
September 24	201	7½	....	
December 10	202	4	....	

The water levels in these wells exhibit but little variation, but such changes as have taken place have been in the direction of loss, the fall measurements of 1905 and 1906 being in each case about 1 foot lower than those of the preceding year. In the Deacon well (No. 149) the fall measurements for 1906 were interfered with by an abnormal rise, probably due to the inflow of surface water; but the 1905 measurements indicate a loss as compared with those of 1904, and the high-water measurements one year apart indicate the same condition. Both of these wells are some distance from any of the washes through which the ground waters are replenished; therefore they exhibit but slight monthly and annual fluctuations. The slow wave of percolating waters, which starts from the washes in all directions through the gravels, with each winter's floods, is very flat indeed before it reaches these more distant wells. Its maximum height in the Ferry well was 2½ inches, reached in February, 1905. In the Deacon well this crest was 10 inches above the low level reached during the previous October.

WELLS NEAR VINELAND.

Two wells at Vineland, near San Gabriel Wash, show this wave of percolating water much more strongly developed. In a case of this kind, where the annual fluctuations are violent, long records are necessary before accurate conclusions can be drawn. In such short records as we now have, general movements of the water plane up or down are obscured by the great range of the seasonal fluctuations. On the face of these records, however, a distinct net gain is observed.

Measurements of fluctuations of water level in wells at Vineland.

Date.	Depth to water.			
	Well No. 87.		Well No. 88.	
	Ft.	in.	Ft.	in.
1904.				
December 14	104	1	93	10
1905.				
January 12	104	6	93	6
February 21	102	10	91	5
March 10	98	9	87	6
April 15	93	11	82	7
May 17	90	8	78	10
June 22	90	11	79	4
July 21	91	4	79	10
August 16	92	2	81	4
September 20	93	9	82	10
1905—Continued.				
November 12	95	9	84	9
December 21	96	7	85	7
1906.				
January 27	97		86	
March 15	95	3	86	5
May 8	83	4	71	10
June 27	81	1½	70	3
August 1	82	11	69	
September 25	85	11	75	1½
December 11	88	10	78	7

The recovery in each of these wells for the two years of observation was 7 or 8 feet annually, with a net gain for the period of 15 feet 3 inches. Not only are the recoveries rapid and of great magnitude, but the annual fluctuations exhibit the wide range of 7 to 15 feet.

WELLS NEAR LORDSBURG.

Two record wells on the mesa northeast and northwest of Lordsburg, belonging to F. H. Massey and Charles Alley (Nos. 67 and 250, Pomona quadrangle), are measured regularly. They serve to record conditions on these valuable bench lands, where water developments have been extensive of late years.

Measurements of fluctuations of water level in wells on bench lands near Lordsburg.

Date.	Depth to water.			
	Well No. 67.		Well No. 250.	
	Ft.	in.	Ft.	in.
1904.				
October 7	....		145	4
November 16	199	1	146	10
December 13	199	3	146	10
1905.				
January 11	19	11	146	9
February 20	199	10½	147	5½
March 11	139	9	147	6½
April 14	200		147	7
May 17	199	11	[a] 152	
June 22	199	4	146	8
July 20	200	2	150	8
August 16	199	9	150	½
1905—Continued.				
September 21	200		150	11
November 11	202	10	152	7
December 20	200	11	152	
1906.				
January 27	201	1	151	5½
March 15	200	2	149	2½
May 8	198	4½	149	6
June 26	197	6	149	½
August 1	196	5½	153	1½
September 24	197	7½	154	4½
December 10	197	3½	154	7

[a] Pumping.

The record of well No. 67 is rather erratic within narrow limits, probably because of variations in the pumping in its vicinity, yet general tendencies are discernible. A comparison of the water levels during the autumn months of 1904 with a corresponding period in 1905 indicates a slight loss of 1 to 3 feet, but when the 1905 and 1906 measurements are compared in the same way a distinct gain of 2½ to 5 feet is indicated, the net result for the two years being a recovery of 1 to 3 feet.

Well No. 250, over a mile farther northwest and near more large pumping plants, shows a decline in both the yearly periods. This decline amounted to 5 or 6 feet for the interval between November, 1904, and November, 1905, but was reduced to 2 or 3 feet for the interval from December, 1905, to December, 1906. The net loss in this well for the two years is 8 or 9 feet.

WELLS SOUTHEAST OF POMONA.

The group of four wells here discussed lies southeast of Pomona, toward the Chino artesian belt. In this direction the water plane and the land surface gradually approach, until in the artesian belt they practically coincide. This fact, as well as the fluctuations of the water table, is illustrated by the following measurements:

Measurements of fluctuations of water level in wells southeast of Pomona.

Date.	Depth to water.							
	Well No. 177.		Well No. 201.		Well No. 181.		Well No. 214.	
1904.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
September 8	89				34	6	8	9
October 6	88	10	58	9½	36	6½	6	6½
November 16	88	10½	60	3	34	10	3	10
December 13	88	10	60	6½	34	10	3	3
1905.								
January 11	88	10	60	10	34	9½	2	5
February 20	89		61	1½	34	7½	2	
March 10	89		61	4½	*a* 35	2	2	1½
April 14	88		60	8	32	10	1	5
May 17			60	11	32	7	2	
June 22	88	11	61	1	33	6	7	5
July 20	90	1½	*a* 62	11	35	4	12	10
August 16	90	5	61	6	35		12	2
September 20	90	8½	61	10	35	6	11	10½
November 11	90	5	62	4	35	8	4	[illegible]
December 26	90	6	62	5	35	7½	4	1
1906.								
January 26	89	6	62	3½	36	8½	4	5½
March 14	90	6	63	1	35	8	3	1
May 8	89	7	63	1½	33	2½	4	[illegible]
June 26			65	4	34	4½	13	[illegible]
August 1	92	2	63	5	35	5	15	8
September 24	92	2	64	4½	36	2½	13	6
December 10			64	11	36	2½	4	10

a Pumping.

Each of the wells of this group shows a distinct though usually slight decline when corresponding dates one year apart are compared. One exception to this general condition appears in the October, 1904, measurement of well No. 181. No measurements were made in October, 1905, but the September and November measurements of that year indicate a higher water plane than on October 6, 1904. With this exception, however, the decline is general. The explanation is probably to be sought in the fact that all these wells lie below the Pomona dike, above which waters are so extensively pumped that but little of the surplus supplied by the heavy rains of 1904-5 and 1905-6 has escaped to this area farther south.

In addition to this general tendency toward shrinkage, exhibited by all of the wells, No. 214, very close to the edge of the artesian basin.

shows interesting annual fluctuations, which are probably due in part to the intense evaporation during the heated term, as well as to pumping in neighboring wells. From January to May, 1905, the water level in this well was but 1½ to 2½ feet below the land surface. From June to September of the same year it stood at 7 to 12 feet below the surface. During the heated term, in the dry atmosphere of this district, evaporation and capillarity act with great force, and draw the ground water from depths of several feet to discharge it as vapor into the air. This action is probably more effective in depressing the water table where it stood initially close to the surface than the drafts made in irrigation during the summer season.

WELLS NORTHEAST OF POMONA.

The four wells of which measurements are given in the subjoined table are located northeast of Pomona, two of them, Nos. 242 and 300, just south of the Santa Fe Railway tracks and three-fourths of a mile east of Claremont, and the other two, Nos. 265 and 265a, in the vicinity of Indian Hill. The buried ridge of red clays and gravels which extends eastward and northeastward from the point of the San Jose Hills, and whose extent beneath the gray gravels of the surface wash is, in a measure, problematical, introduces in the wells of this neighborhood an element of considerable uncertainty. One well may yield a good supply of water, while another near by, which happens to penetrate this older alluvium, will be dry; or the water level may stand at a certain elevation in one well and at a much lower or higher point in an adjacent well just across a buried ridge or "dike" of these dry gravels. There are many illustrations in the area northeast of Pomona of erratic conditions of this kind.

Measurements of fluctuations of water level in wells northeast of Pomona.

Date.	Depth to water.							
	Well No. 242.		Well No. 300.		Well No. 265.		Well No. 265a	
1904.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
October 6	158	5	157	10	....		....	
November 16	156	2	154	3½	62	1	40	4½
December 13	155		153	2½	61	10	39	7
1905.								
January 11	153	1½	151	5	62	2	40	3½
February 20	151	1	149		62	1	40	1
March 10	150	2	147	10	61	10½	39	
April 14	148	7	146	7	59	4	37	6
May 17	147	1	145	1	59	1½	37	1
June 22	148	7	146	5	57	5	35	5
July 20	150	10	149	8	57		35	3
August 16	150	8	150	8	59	7	37	4
September 21	152	6½	151	4	58	6	38	3
November 11	152	1	156	8	58	4½	36	3
December 20	149	1	....		57	3	35	7
1906.								
January 26	149	6	....		56	9½	....	
March 14	144	3	....		53	2½	34	3
May 8	141	2	....		54	4	32	6
June 26	132	4	....		53	3½	31	6½
August 1	146	8	147		54	1	31	11½
September 24	149	8½	....		53	3½	30	6½
December 10	149	8	....		56	10	33	10½

This group, lying for the most part above the Pomona dike, contrasts in a marked way with the group last discussed, which lies entirely below it. The three wells in which continuous measurements have been maintained for two years all show substantial recoveries; but, curiously enough, the recoveries were more marked during the first than during the second of the two years. There seems to have been no cumulative effect, such as some other wells exhibit, in consequence of the two successive years of heavy rainfall. The net recoveries for the period from December, 1904, to December, 1906, amount to 5 or 6 feet in each well.

WELLS IN SAN GABRIEL RIVER BASIN.

The group of five wells here discussed lies west of the San Gabriel River in the lower part of the San Gabriel basin. The wells are arranged in the table in the order of their distance from the river, which is the principal source of the water by which the recharge of the basin is effected. In considering these measurements it is well to remember that the lower San Gabriel basin has one of the best supplies of underground water in this part of the State, and that it has not been too heavily drawn upon, as is true of many other moist-land areas. The water plane, therefore, was not depressed excessively during the dry period. Seasonal fluctuations normally are not as great in the Elmonte region as at points like Vineland, higher up on an alluvial fan, but are greater than at places lower down, as in the Paso de Bartolo, for example. The recovery which these wells exhibit is regarded rather as a return of the waters to their normal levels, and an elimination of the effects of drought, than as a replacement of waters withdrawn by development.

The magnitude of the seasonal variations and the amount of the net gain shown in these wells decrease with the distance from San Gabriel River. The net improvement, only the December measurements two years apart being considered, varies from 10 inches in well No. 476 to 7 feet 9 inches in well No. 164, and the range of annual fluctuations from about 3 feet to 6 or 8 feet.

In only one of the numerous canals heading in or just above the Paso de Bartolo and depending on the waters that rise there has it been necessary to install pumping machinery to keep up the supply during the dry years through which the country has passed, and unless there are further extensive developments above the pass the supply to these canals, which now receive gravity water, should remain sufficient. It is indeed possible that considerable amounts of water could be withdrawn from the Elmonte field by pumping without interfering with the supply below, because a slight lowering of the water plane, where it stands very near the surface, would lessen the loss by evaporation from these moist lands during the summer months, and the water thus saved would become available for irrigation. It can be saved only by pumping and so depressing the surface of saturation.

Measurements of fluctuations of water level in wells in lower part of San Gabriel basin.

Date.	Depth to water.									
	Well No. 164.		Well No. 478.		Well No. 141.		Well No. 476.		Well No. 107.	
1904.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
November 8			22	5			21	3		
December 9	21	5½	22	6½	16	2	19	6	72	11
1905.										
January 4	21	5	22	6	16	1½	20	1½	72	10
February 9	20	8	21	9	16	3	20	0	73	0
March 17	17	10	20	1	13	8	19	3	72	10
April 12	15	10	18	1	13	2	18	4	72	7
May 10	14	8	16	8	14	8	17	8	[a] 74	6
June 13	13	8	16	11	14	6	18	7	73	4
July 12	13	9	17	5	13	1	18	11	73	3
August 10	15	9	16	8	13	5½	19	2	74	1
September 13	16	10	17	5	14	4	20	0	[a] 75	8
November 7	17	3	18	2	14	1	20	3		
December 18	17	0	18	0	13	9	21	3	73	0
1906.										
January 24	17	4	18	9½	13	8½	19	10	76	2½
March 22	15	4	17	3	12	6	18	11	72	8½
May 5	12	8	14	4	11	8	18	1	72	7½
June 25	11	9	12	9½	11	5	18	4	72	8
July 31	12	2	12	11½	11	10½	18	8	72	3½
September 20	13	5½	14	1	12	2½	19	6	72	1
December 17	13	8	14	7½	11	9	18	8	71	4

[a] Pumping.

WELLS IN PASADENA BASIN.

The wells of the next group are in the Pasadena basin above the Raymond Hill dike. They are in a region in which there is relatively little annual fluctuation, because it is far from the regular flood channels and receives its general supply only after it has percolated long distances through the gravels. The well of the group which exhibits the annual pulsations most clearly is No. 40a, on the Titus ranch at Sunny Slope. This well is in the old artesian basin, and the annual variations of its water level are probably due, in part at least, to summer evaporation, as in the well above Chino. While the record of this well is short and somewhat broken, it seems to indicate a slight gain. The record of No. 474 is also imperfect, but indicates an improvement in conditions. On the other hand, Nos. 56 and 17 indicate slight net losses for the period spanned by the measurements, although a gain of 2 inches appears for the last year of the period in No. 17.

Measurements of fluctuations of water level in wells in Pasadena basin.

Date.	Depth to water.							
	Well No. 474.		Well No. 40a.		Well No. 56.		We No. 1	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	
1904.								
September 2	44	3			73	3	122	[illegible]
October 5	44	10			73	10	122	[illegible]
November 8	44	0			73	11	122	[illegible]
December 10	45	1½	13	6	74	6	122	[illegible]
1905.								
January 4	43	6	10	4½	74	6	122	1
February 9	43	1	8	7	74	4	122	[illegible]
March 17	43	0	8	6			122	[illegible]
April 12	39	11	7	8	73	8	122	[illegible]
May 10	39	4	8	1	73	5	122	[illegible]
June 13			11	6	73	5	122	[illegible]
July 12	41	9	16	1	74	0	123	3
August 10			19	2	74	5	123	[illegible]
September 13			16	2	75	0	124	[illegible]
November 7			12	10	75	0	124	[illegible]
December 18			10	7	75	9	123	[illegible]
1906.								
January 24	41	5	10	3			123	[illegible]
March 22	41	0	10	0	74	6	123	[illegible]
May 5			8	4	74	9	122	[illegible]
June 25					74	6	122	[illegible]
July 10	41	2						
July 31			18	3	75	3½	123	[illegible]
September 20			16	9½	76	1½	123	10
December 17			14	4½	77	1	123	1½

SUMMARY OF RESULTS OF WATER-PLANE MEASUREMENTS.

The wells which have been selected for measurement within the foothill belt are distributed widely over it. They include those favorably situated in relation to pumped areas and flood channels and those less favorably situated. They represent the greater number of the important local basins, and are probably to be depended on to indicate general conditions fairly. Measurements of 28 of these wells have been given in the tables. Fifteen of these show a net gain for the two-year period and 10 show a net loss, while 3 are indeterminate because of incomplete measurements. The year from September, 1905, to September, 1906, was more effective than the preceding year in restoring water levels, as is illustrated by the fact that 16 wells showed net gains for 1906, while net losses are registered in 10, 2 being indeterminate; whereas only 14 register a gain in water levels in 1905, and an equal number show losses. The gains, as has been indicated, are in wells situated close to drainage lines, and the losses in wells farther away from them. Fortunately the pumping plants of the more important systems are thus favorably situated, and a majority of them are gainers by the partial restoration of water levels which has taken place within the past two years. A smaller number are not within the belts that are thus favorably situated.

On the whole, while there has been a definite improvement in conditions in some of the basins during the period of observations—a period of marked excess in rainfall—the fact that water levels have continued to decline steadily in others, when conditions are so favorable for recovery, indicates excessive drafts in these latter localities at least. The general conclusion reached two years ago, that there are serious overdrafts on the ground water-basins, seems to be supported fully by the more abundant evidence now available.

IRRIGATION ENTERPRISES.

INTRODUCTION.

In 1888 Wm. Ham. Hall, State engineer of California, published his volume on "Irrigation in Southern California." This work included an account of the organization and engineering features of practically all the irrigation enterprises in existence in the southern part of the State at that time. The work has been extremely useful to all who have desired to gain a general idea of irrigation development in this part of the State. In the foothill belt many enterprises have been organized since the publication of Hall's work, and the conditions under which some of the older ones operate have been altered by reorganization and otherwise. Especially important have been the development of ground waters and the organization of companies for this purpose, or the extension of the functions of older gravity companies to enable them to utilize ground waters.

It has seemed worth while to present with this volume an account of the more important irrigating companies now operating in the foothill belt. For the earlier history of those enterprises which had been organized before 1888, Hall's volume has been consulted. For developments since, including the organization of new companies as well as changes in the older ones, various sources of information have been utilized, but in the majority of cases officers of the companies themselves have been consulted.

In the collection of this material the writer desires to acknowledge his indebtedness to Mr. W. N. White, field assistant, who gathered much the greater part of the information. Acknowledgments are due also to many engineers, not all of whom it is possible to mention. Mr. T. D. Allin and Mr. E. T. Wright have been consulted especially.

In presenting this material the plan followed has been to discuss the companies in the order of their distribution from east to west along the foothill belt. Those first described, therefore, are the Cucamonga enterprises, and those last described are the companies operating in Verdugo Canyon.

ETIWANDA WATER COMPANY.

The Etiwanda Water Company controls the waters of Day and Etiwanda canyons and utilizes these waters in the irrigation of about 1,200 acres of the Etiwanda colony lands, lying from 1½ to 4 miles north of the Santa Fe Railway at West Etiwanda station. The rights of the company date back to a number of filings by George Day and others from 1867 to 1873. These rights were afterwards consolidated, passed through several transfers, and have been confirmed in a number of suits.

The present company was organized by George and W. B. Chaffey in 1882. It is capitalized at $500,000, divided into 5,000 shares at a par value of $100 each; 2,300 shares have been issued, and the present market value is reported to be about $35 per share. The shares are not appurtenant to the land, but 90 per cent of them are held by irrigators, of whom there are about 75 in the colony.

As the colony lands were originally sold, one share of stock in the water company was transferred with each acre of land, and each 8 shares of stock entitled the owner to 1 miner's inch of water. It is customary to deliver the water monthly in 36-inch heads to each 10-acre tract, this giving approximately the usual duty of 1 inch to 8 acres, at a cost to the irrigators of $1.45 per acre annually.

The water is brought from the canyons through 1½ miles of V-shaped wooden flume and 2 miles of 10 and 12 inch pipe to a distributing box at the head of the colony lands. Below the distributing box are about 20 miles of 7 to 10 inch pipe, through which the water is conducted to the individual holdings. The reported cost of the pipe system is $23,000. There are no auxiliary wells, as in the case of many modern irrigation systems in southern California, ground waters beneath the Etiwanda district being too deep for profitable development.

Citrus fruits and grapes are the principal crops grown.

Only a few measurements of the flow from Day and Etiwanda canyons are available. These are quoted from "Irrigation in Southern California," by Wm. Ham. Hall.

Flow measurements in Day and Etiwanda canyons.

	Miner's inches
September 1, 1882	224.5
July 15, 1884 (noon)	211
July 15, 1885 (7 a. m.)	170
August, 1885	50
July 15, 1887	189
July 15, 1888	[a] 356
July 16, 1888	[b] 421.31
August, 1888	150

HERMOSA WATER COMPANY.

The next important irrigating enterprise along the foothills west of Etiwanda is that of the Hermosa Water Company. Lying along the slope, 3 miles from Etiwanda and about 1 mile north of Cucamonga.

---

[a] 28 miner's inches considered as developed water.

[b] Calculated from slope and section of flume.

the Hermosa tract originally embraced 480 acres of land, upon which the waters of Deer Canyon and its tributaries are used.

The Hermosa Water Company was organized by owners of realty who had purchased lands and undivided interests in the waters of Deer Canyon from Adolph Petch or from the Hermosa Land and Water Company, organized by Petch in 1882. The water company was incorporated in October, 1887, with a capital stock of $192,000, divided into 1,920 shares with a par value of $100 per share. Four shares of stock were issued to each acre of the original tract, and each owner received a share of the available water proportional to his holdings of stock and acreage.

For many years the canyon flow was sufficient for the needs of the colony, but after the dry years of the late nineties the supply from the mountains so diminished in volume that it became necessary to augment it from some other source. In 1901 the company purchased 80 acres of land from the Cucamonga homestead, one-half mile north and west of the Hermosa tract, sunk a well on this property, and installed a pumping plant (No. 56, Cucamonga quadrangle).

The water from Deer Canyon and its branches, Calamity and Hermosa canyons, is collected by means of about 4 miles of 2-, 3-, and 4-inch pipe, and carried out of the canyon and down the slope, a distance of nearly 4 miles, through an 8-inch cement main, to a reservoir at the head of the colony lands. Just below the mouth of the canyon a branch pipe from Alder Canyon joins the main line. The company is entitled to the water of Alder Canyon up to 20 miner's inches. The upper part of the main-canyon conduit, which was originally an open flume, has been replaced by an 18-inch cement pipe. Delivery from the reservoir to the lands of the irrigators is made through 4- and 8-inch pipe.

The summer flow from Deer Canyon and its branches varies with the rainfall of the previous winter. The company reports that in July, 1903, it received 70 inches of mountain water, an average of 45 inches through the irrigating season of 1904, and 80 inches in August, 1905. Pumped water is used as an auxiliary to the canyon flow. During the season of 1902 the plant, consisting of a 20-horsepower gas engine and Ames Fulton pump with a capacity of 30 miner's inches, was in operation one hundred and forty days consecutively. During the season of 1903, following a wet winter, the flow from the canyon supplied the needs of the company and the pumping plant was not used. Again during the summer of 1904 mountain water was short in quantity, and pumped water was used freely in making up the deficiency.

The water supply is divided into heads and distributed to the irrigators in rotation every twenty-four days. The time given to each irrigator varies with his holdings of stock. A man owning 40 shares is given twenty-four hours' run of a half head every twenty-four days.

The cost of operating and maintaining the system is prorated among the stockholders according to the proportion of stock held by each, the annual cost of water varying with the volume of pumped water used. The actual cost of pumping a 30-inch head for twenty-four hours is $5.25 under present conditions. The only expense attached to the delivery of canyon water is the cost of keeping the pipe lines in repair, the secretary's annual salary of $50, and the zanjero's fees. The average cost of all water used, gravity and pumped, during the past four seasons, is reported to have been $5.75 per acre per annum. There are 40 irrigators in the colony, and at the present time about 500 acres are supplied with water. The company owns 1,200 acres of land in Deer and Calamity canyons, which were homesteaded by stockholders and deeded to the company in order to protect its water rights there.

The company's investment is as follows: Pumping-plant site, 80 acres, $4,900; reservoir site, 2½ acres, $125; pipe system and reservoir $4,000; well and pumping plant, $3,300; total, $12,325.

The right to use the water for power purposes, reserved by the promoters at the time the land and water rights were sold, is now held by the company.

IOAMOSA WATER COMPANY.

The Ioamosa tract, in which there are 500 acres of irrigated land, lies about 1 mile north and west of the Hermosa colony. The lands are a part of the old Cucamonga Homestead Association's property, and the water with which they are supplied comes entirely from Cucamonga Canyon and belongs in part to the Cucamonga Development Company.

The Ioamosa Water Company was incorporated in 1883, with a capitalization of $50,000, divided into 500 shares, with a par value of $100 per share. The company holds title to $\frac{86}{300}$ of the surface and developed flow of Cucamonga Canyon and leases the balance of all water derived from that source from the Cucamonga Development Company at a yearly rental of $500. The water procured by diversion of the surface flow and by 700 feet of tunnel intended to intercept the underflow is brought to the mouth of the canyon through a 30-inch conduit 3,400 feet long. Thence it is taken diagonally across the slope in a southeasterly dircetion in a 12- and 8-inch cement line to a small reservoir at the upper end of the colony lands. Below the reservoir about 2 miles of 8-inch vitrified and 6-inch iron pipe have been laid for delivering the water to the irrigators.

It is reported that from 10 to 40 inches are developed in the tunnel, while the total flow, natural and developed, is said to vary from 30 to 100 inches. The duty of water in the colony is reputed to be 1 miner's inch for each 7½ acres, distributed in two 40-inch heads, twice each month to each 20-acre lot. Twenty-three irrigators are supplied, and the cost of water is about $2 per acre per year.

CUCAMONGA LANDS AND CUCAMONGA WATER COMPANY.

What are known as the Cucamonga lands are situated in the western portion of San Bernardino County, between the San Bernardino base line and the Southern Pacific Railroad, which is about 4 miles distant on the south. They extend eastward about 4 miles from the Ontario colony lands and Cucamonga Wash, and include in the aggregate between 8,000 and 9,000 acres, about one-third of which is irrigated, while another one-third is cultivated as vineyard but is not under irrigation.

The well-known Red Hills, famous as water-bearing lands, lie in the northwest corner of the Cucamonga tract, and the developments in and adjacent to these hills supply the water used for irrigation in the Cucamonga district and a portion of that used farther west by the San Antonio system.

The Cucamonga Water Company, which at present supplies nearly all of the water used in the district, was incorporated in December 1887, by certain members of an older organization called the Cucamonga Fruit Land Company. This company owned all the waters flowing from the "West ciénaga," the moist lands west and north of the Red Hills, and one-half of the waters flowing from the "East ciénaga," a similar area lying in and northeast of the Red Hills. At that time the total amount of water thus owned was between 250 and 300 miner's inches. The other half of the east-side waters belonged to the Cucamonga Vineyard Association, and a total of about 400 acres was under irrigation by both organizations, the Vineyard Association being the heaviest water user.

In addition to these rights there were certain obligations outstanding against the Fruit Land Company. The "Class A" rights comprised 33.84 miner's inches due a certain group of "old settlers." The "Class B" rights comprised 67.75 miner's inches due another group of "old settlers," who had signed agreements to accept 1 miner's inch of water for each 10 acres of land owned by them. Other obligations constituting classes "C" and "D" were agreements to furnish water, by a company to be formed later, to lands which had been sold earlier by the Fruit Land Company. Something more than 300 inches was conveyed under these two classes.

All of the Fruit Land Company's rights to waters that were then flowing, all of its lands which were then recognized as water-bearing lands, and all of its obligations were conveyed to the Cucamonga Water Company at the time of its organization in 1887, and in addition the older company contracted to develop and deliver to the purchasing company enough water to fulfill all of the obligations which had been conveyed with the rights in the deed.

In fulfillment of the terms of this contract, the Fruit Land Company, during the years 1888, 1889, and 1890, expended from $75,000 to $100,000 in developing water by sinking wells and driving tunnels, so that when measurements were made in July, 1890, it was found that about 500 inches of gravity water, in part natural flow and in part the result of the development work, belonged to the Cucamonga Water Company. This amount was more than enough to satisfy the rights outstanding at that time.

During the dry period which followed, the flow from these various sources decreased, until in 1899 only 190 inches of gravity water were available, and the water company was forced to augment its supply by pumping from the Lone Star Springs above the base line. During this year the Fruit Land Company bored a deep well on the lands which it still held on the west side but which, at the time of the transfer of its rights to the Cucamonga Water Company, had not been recognized nor classified as water-bearing lands and were therefore not included in the transfer. This well at first yielded 100 inches of water, and at about the time of its development the Fruit Land Company contracted to deliver to the San Antonio Water Company 100 inches of water for $100,000. Suit was brought by certain stockholders of the Cucamonga Water Company against both the Cucamonga Fruit Land Company and the San Antonio Water Company to prevent the consummation of the sale, but judgment was rendered in 1900 against them and the sale was confirmed. During the summer of 1900 the control of the Cucamonga Water Company passed into the hands of the stockholders who had brought this suit, through the purchase of outstanding stock, and they also bought of the Cucamonga Fruit Land Company an interest in all the lands still owned by that company that could be regarded as water bearing on the east and west sides of the Red Hills.

Since 1900 three or four wells have been put down, the tunnel has been extended, and a pumping plant known as the Lone Star system has been installed, so that stockholders have received their full quota of water, although gravity water has constantly decreased. This decrease has been particularly marked in the Y tunnel and in the creek near the old Cucamonga Hotel that drains the original East ciénaga. It is stated that the original supply from these sources was from 150 to 500 inches of water, and that now (1906) it is less than 5 inches. The Cucamonga Water Company regards this decrease as due to the battery of wells and pumps installed by the San Antonio Water Company north and west of the Red Hills and used extensively as an adjunct to the San Antonio system. Suit has therefore been brought against the San Antonio Company to prevent pumping from these wells and to recover damages for property claimed to have been destroyed through this pumping. This suit was still in the courts in 1906.

When the Cucamonga Water Company was organized, in 1887, its capital was fixed at $100,000, divided into 10,000 shares at $10 per share. One share, representing one-tenth of a miner's inch of water continuous flow, was to be distributed with each acre of land sold. In 1901 or 1902, when a consolidation of interests was effected by the purchase of stock and rights owned by the Cucamonga Fruit Land Company and others, the capital stock was increased to $100 per share and bonds to the value of $250,000 were issued. Although the capitalization of the company was effected on the basis of 10,000 shares, the issue of stock has been controlled by the quantity of water available, not more than 10 shares being distributed for each inch of water owned, the amount of the water being determined by measurements made on July 15 of each year. The greatest amount of stock outstanding at any time was 4,500 shares, and this has been reduced by purchase to less than 3,000 shares.

In addition to the rights and lands which have been referred to, the company owns a number of tunnels, wells, and reservoirs, constructed generally by the Cucamonga Fruit Land Company in fulfillment of the contract entered into by it at the time of the organization of the Cucamonga Water Company. The west side or Eddy tunnel is one of these structures. It was originally a timbered tunnel, 3,600 feet long, but the timbering has been replaced by a 30-inch concrete pipe line. The charges for the maintenance of this line are shared with the San Antonio Water Company, which also uses it, the proportion of water in the tunnel belonging to each company determining the proportion of the running expenses borne by each. The east side or Y tunnel, just east of the old Cucamonga Hotel, also belongs to the Cucamonga Water Company, and, like the Eddy tunnel, has been replaced by a concrete pipe line. At the head of each arm of the Y is a well, but since 1903 this work has yielded no water. A third tunnel, 3,000 feet in length and running northwest from the center of sec. 3, on Hellman avenue, extends through a 35-acre tract belonging to the Cucamonga Water Company and into the Lone Star tract. Eight or ten artesian wells discharge into this tunnel, but the greater part of the water which it yields is supplied by the upper well of the Lone Star group. In addition to these development works the company owns an adequate distributing system, which includes three reservoirs and 20 or 25 miles of iron pipe that serves all of the lands under irrigation.

All of the water distributed is delivered under pressure in 30-inch heads, each 10 shares of stock entitling the holder to a flow of 30 inches for one day in each month.

The fixed charges of the company, comprising the interest charges on the bond issue, amount to $15,000 annually. The maintenance charges amount to about $6,000 per year, and these expenses are met by annual assessments on the stock of $10 or less per share.

OLD SETTLERS WATER COMPANY.

The Old Settlers Water Company was organized by stockholders of the old Cucamonga Fruit Land Company, who held rights to 33.84 inches of the surface flow of the Red Hills East ciénaga. When this ciénaga ceased to flow, because of the dry years and the draft on the underflow caused by the tunnels and pumping plants in the vicinity, these irrigators found it necessary also to resort to pumping. With this purpose in view the present company was incorporated June 21, 1902, and capitalized at $33,840, divided into 33,840 shares of $1 par value each. Land was purchased three-fourths of a mile north of Cucamonga, a well was sunk, and a pumping plant, consisting of an 18-horsepower gas engine and an Addison deep-well pump, was installed (No. 53). This plant pumps about 33 inches of water. The distributing system consists of 1½ miles of 6-inch and 1 mile of 8-inch concrete and vitrified pipe. Two hundred and seventy acres are irrigated and the water is delivered in 33-inch heads in rotation, every thirty days, on the basis of 1 inch constant flow to 8 acres. The cost is $10 per acre per annum. The water is not appurtenant to the land, but stock is held exclusively by irrigators. Oranges and deciduous fruits are raised.

SUNSET WATER COMPANY.

The Sunset Water Company was incorporated January 10, 1901, with a capital stock of $60,000, divided into 2,400 shares, all of which have been issued. The company was organized by stockholders of the Cucamonga Water Company for the purpose of increasing their water supply. Thirty acres were purchased in the water-bearing lands northeast of the Red Hills, where a well was sunk and equipped with machinery for pumping. The pumping plant (No. 54, Cucamonga quadrangle) consists of a 14-horsepower motor and a Garrett pump, and has a capacity of 30 inches. The water is raised to the level of a discharge tunnel 30 feet below the ground level at the well, and brought to the surface through the tunnel, 1,000 feet below the plant. From this point the water is distributed to the lands of the irrigators through 3½ miles of steel pipe 4 to 12 inches in diameter. In practice about 1 inch to 10 acres is used, though there is no restriction on the amount that may be used. Six hundred acres are partially irrigated. The water is distributed in 30-inch heads monthly. The cost to the irrigators is $10 for a twenty-four-hour run of 30 inches. During the three seasons preceding the spring of 1904 the water level in the company's wells declined 4 to 6 feet annually, and with the lowering of the water plane the capacity of the plant has dropped from 42 to 30 inches. The plant is in operation about six months of each year.

ONTARIO COLONY AND SAN ANTONIO WATER COMPANY.

HISTORY OF RIGHTS.

The Ontario colony occupies lands lying immediately west of Cucamonga Wash and extending in a strip 1 to 3 miles wide from the mesa at the foot of the San Antonio Mountains down the slope for a distance of about 6 miles. On the west the upper part of the colony tract is separated from the Claremont and Pomona irrigating districts by San Antonio Wash, and the lower part of the tract adjoins lands that are covered by the Del Monte Irrigating Company of Pomona. On the east Cucamonga Wash lies between the colony lands and those of the Cucamonga irrigators.

About 5,000 acres are under irrigation in the Ontario district. Gravity water is supplied to the tract from San Antonio Canyon and from the Cucamonga tunnel in the water-bearing lands of the Red Hills, which lie to the east of the colony, midway between North Ontario and Cucamonga. The canyon and tunnel flow is supplemented by pumped water derived from wells north of the Red Hills on the east and from the neighborhood of Claremont and Indian Hill on the west.

By far the greater part of the water supplied to the colony is owned and distributed by the San Antonio Water Company. The Ontario Water Company is an adjunct organization, whose stockholders belong to the San Antonio Water Company but pump independently in case of a shortage. Several hundred acres lying west of North Ontario are supplied with pumped water by the plants of the Upland, Mountain View, and Canyon Ridge water companies.

The San Antonio Water Company is a mutual company, one of the early organizations of its kind in the State. Stockholders are owners of realty, and water can not be delivered by the company to others than stockholders. The company was incorporated in October, 1882, by the Messrs. Chaffee, who owned the water rights on the east side of San Antonio Canyon, and these rights, together with diversion works, conduits, and pipe system, were later transferred to the San Antonio Water Company. This company was organized with a capital stock of $1,500,000, divided into 15,000 shares of a par value of $100 each; 6,064 shares have been issued. In 1882, by agreement between the Chaffees and the Pomona Land and Water Company, which owned water rights on the west side of the canyon, the surface flow at a point about 1 mile above the mouth of the canyon was divided equally, and a joint diversion dam was constructed. About 1896 the San Antonio Water Company acquired what was known as the Gird or Dexter interest in the canyon, consisting of several hundred acres of land, together with a prior right to 20 miner's inches of water. In 1897 the San Antonio Water Company and the Pomona Land and Water Company entered into an agreement by which the latter conveyed to the San Antonio Water Company all of its interests in the canyon, in return for which the San Antonio company agreed that whenever the total flow in the canyon was 624 inches or less the Pomona company was to receive one-half, and that all water in excess of 624 inches should belong to the San Antonio company. After entering into the above agreement the San Antonio company began to divert the 20 inches of Gird or Dexter water, piped it past the division dam, and continued this diversion for five years, when suit was brought by the Pomona Land and Water Company; but January 6, 1905, Judge Allen rendered a decision in which he held that the San Antonio company had acquired a good title to this water.

In 1902-3 the Ontario Power Company laid a conduit from the south line of sec. 36, T. 2 N., R. 8 W., diverted the canyon flow at that point, and piped the water along the west side of the canyon to a point on the hills above the division dam and constructed a power plant. This conduit is a 30-inch cement line, except where iron pipe is used in inverted siphons in crossing side canyons. It is laid partly in trenches and partly through tunnels. For a year previous to the laying of the conduit careful measurements were taken by expert hydraulic engineers at the south line of sec. 36 and at the division dam 3 miles below, and it was determined that 19 per cent of the water was lost from the natural flow of the canyon stream between the two points. After the completion of the conduit by which this loss was prevented, the Ontario Power Company laid claim to and appropriated 20 per cent of the flow of the canyon as salvage. This claim was subsequently disallowed by the courts, which ruled that the Pomona irrigators were entitled to one-half of the saving effected through the higher diversion of the Ontario Power Company.

It became apparent in the early days of the colony that there would not be sufficient surface water from San Antonio Canyon to supply all of its requirements, and steps were taken to procure additional water from other sources. In January, 1883, a tunnel was begun in the gravel bed of the canyon about 1 mile above its mouth; it was gradually extended during the succeeding years, and completed about 1889. This tunnel has a sectional area of 3½ by 6½ feet. It is 3,000 feet in length and is reported to have cost about $50,000. The upper 600 feet penetrates bed rock below the wash material of the creek, the bottom at the upper extremity being 110 feet below the bed of the creek. F. E. Trask reported the average July output from this tunnel for 15 years previous to 1903 as 116 miner's inches. B. C. Shepherd, secretary of the company, states that the flow varies from 50 to 150 inches and averages about 75 inches during the irrigating season. The creek waters and the San Antonio tunnel waters are brought together in the main ditch about 500 feet below the mouth of the tunnel.

West of the Red Hills, in what is known as the West ciénaga, a tunnel 3,600 feet in length was constructed by the Cucamonga Fruit Land Company for the Cucamonga Water Company in the late eighties. This tunnel, which has since been extended to 4,000 feet or more in length, is known as the Eddy or Cucamonga tunnel. Some time after its construction the San Antonio Water Company acquired water-bearing lands in the West ciénaga, a 20-foot right of way, and one-half interest in the carrying capacity of the tunnel. In 1889 a 22-, 24-, and 30-inch cement pipe was laid from the division box at the mouth of the tunnel to North Ontario, and connected with the system there. Several wells were sunk along the upper course of the tunnel, and cut to flow into it at depths of 90 to 110 feet from the surface. It is known that one of these wells (No. 80, Cucamonga quadrangle) was flowing in 1905, and it is supposed that others were flowing then, but this could not be ascertained. The water from this tunnel, which belongs in part to the Cucamonga Water Company, is apportioned in a division box at the mouth of the tunnel, and is conducted thence to the distributing systems of the owning companies. Of the Ontario companes' share of the Cucamonga tunnel gravity water, the San Antonio Water Company receives the first 130 inches and the Ontario Power Company the balance. The average flow received by these two companies during the irrigating season has been reported as 150 miner's inches.

Previous to 1893 the canyon and tunnel water had been nearly sufficient for the needs of the colony. Beginning at about that time, several dry years followed in succession, causing a decline in the canyon flow and an extreme shortage of water. As the necessity for more water became pressing, the company sought relief through the further development of underground waters, which had been begun in a small way in the Del Monte ciénaga in 1889. Nine hundred and fifty acres of land were purchased east of the colony, north of Sixteenth street above the Cucamonga Red Hills, and in 1898 a well was sunk (No. 75, Cucamonga quadrangle), a pumping plant installed, and 16- and 20-inch vitrified pipe laid to connect with the canyon distributing system. At various times since then four additional plants have been installed on this property, the last in 1904. Water rights have also been acquired on the adjoining Rubio property, where a plant has been installed, and still farther east two other wells, known as the Haskell wells, have been purchased and equipped with pumping plants.

In all, the San Antonio Water Company owns and operates eight plants (Nos. 73–79, Cucamonga quadrangle) in the Red Hills district, with a combined pumping capacity of 450 inches. The wells are seldom pumped to their full capacity, and the output varies with the needs of the colony and the fluctuations in the gravity flow from San Antonio Canyon and tunnel and the Cucamonga tunnel.

In addition to these more important Sixteenth street and Red Hills wells, the company has four wells, two of which are equipped with pumping plants, in the old Del Monte ciénaga, near Claremont. The output of the two wells pumped in this field is given as 75 miner's inches. In the operation of these wells, electric power supplied by the adjunct corporation, the Ontario Power Company, is used. This power succeeds the gas and steam engines which were used in the early pumping operations.

In 1898 the company acquired the Bodenhammer well (No. 88, Cucamonga quadrangle) and a tunnel located along the west line of the colony lands, about 1½ miles below the mouth of San Antonio Canyon. Since the well was sunk and the tunnel driven the water plane in this vicinity has dropped many feet below the tunnel level.

The San Antonio company also owns 1 mile of tunnel, which was driven into the mesa at the foot of the mountains just west of Cucamonga Wash. This work is reported to have cost $80,000. There is no summer yield during dry years, but in winter a moderate amount flows from the tunnel.

PIPE LINES AND CONDUITS.

The Ontario colony is piped throughout with carrying lines, constructed principally of cement and vitrified clay, and ranging from 8 to 40 inches in diameter. Distributing mains and diagonals have been laid in such a manner that the supply from the various sources can be readily shifted to different parts of the tract. Water in the pipes is not under pressure, but the onward flow is partially cut off by gates which hold the water and cause it to rise to the top of a short standpipe or turn-out, placed at the highest point of each 10-acre lot. Domestic water is carried from these turn-outs through iron pipes to the homes of the irrigators.

OPERATION AND MAINTENANCE.

Theoretically the San Antonio Water Company delivers 1 miner's inch of water to each 10 acres on each 10 shares of stock. In practice the available supply is prorated to the stock and a twenty-four-hour run is given each 10 acres monthly, but the size of the irrigating head varies with the water supply, though the average is about 30 inches. During the irrigating season of 1905, succeeding a winter of excessive rainfall with a large canyon flow, the company expected to deliver 40-inch heads throughout the season.

ANNUAL COST.

The average cost of operating and maintaining the system of the San Antonio Water Company is $60,000 per annum, and the average cost per acre varies from $10 to $12. Funds for meeting obligations in the shape of interest, sinking fund, maintenance, and expenses are derived from assessments on the stock. A part of the floating indebtedness was paid off during 1904, and total assessments of $25 per acre were levied that year. Other payments were made in 1905, and an assessment of $20 per acre was collected.

ONTARIO WATER COMPANY.

The Ontario Water Company was organized in 1900 by stockholders of the San Antonio Water Company who did not hold enough stock in that company to insure them a sufficient water supply in years of light rainfall. The organization was effected on the basis of a capitalization of $100,000, divided into 1,000 shares with a par value of $100 each. In 1905 six hundred and twenty shares had been issued, 495 to irrigators and 125 to nonresidents, and the market value was reported by the company's officers to be $50 per share.

In 1900 a tract of 134 acres lying east and south of Indian Hill was purchased at a cost of $34,000. Six wells were at on cesunk on the tract and a pumping plant was installed, the expenditures for these purposes being $10,000. The plant consists of a 70-horsepower steam engine and a Smith-Vaile air compressor, by which all the wells which lie within a radius of 600 feet of the plant may be pumped. The water, about 70 miner's inches, is conducted through a 14-inch line about 3 miles in length to the tract owned by the stockholders. This tract lies about 1 mile southwest of Upland. As the water is used as an auxiliary to the canyon supply, it is necessary to pump only during the summer months, and not then if the flow from the canyon is large. The plant was in operation during four months in 1900, 1901, and 1902, but was not used in 1903.

The water is distributed in 30-inch heads and is prorated to stockholders according to their interest. The cost of the water is given at 67½ cents per hour for a 30-inch head; that is, 2¼ cents per hour-inch.

In order to carry out the necessary improvements for developing and distributing the waters, bonds amounting to $25,000 were issued in July, 1900. Two thousand dollars of these bonds fall due annually for ten years, beginning with 1906, and $1,000 each year thereafter until they are paid.

POMONA IRRIGATION.

RIGHTS.

The flourishing district about Pomona and Claremont derives its irrigating water from San Antonio Canyon and from numerous wells and pumping plants that have been installed, mainly in the old ciénaga lands in the vicinity of Claremont and about the eastern point of the San Jose Hills. (See Pl. I, *C*, *D*, p. 8.)

The rights to the flowing waters of the canyon date back to Ignacio Palomares, one of the early owners of the San Jose rancho, and to N. Alvarado, a squatter on this tract. Both of these men built ditches from San Antonio Creek and acquired rights to its waters. These rights were subsequently transferred to American purchasers and have been subject to adjustment as between the Pomona and Ontario users, the former holding the old rights to the west-side waters from San Antonio Canyon, and the latter to the east-side waters. As the matter stands at present, the San Antonio Water Company, supplying Ontario and vicinity, and owners of the earliest right on the stream, the Gird or Dexter right, are entitled to the first 20 miner's inches flowing from the canyon. After this amount is taken out, the remainder is divided equally between the east-side and west-side users, until it exceeds 624 inches. All of the flow in excess of this amount belongs to the San Antonio Company, representing the east-side ownership. The Pomona users may therefore receive not to exceed 312 miner's inches of this water, and will receive less than that if the canyon flow falls below 644 inches.

CANYON WATER COMPANY OF POMONA.

About 83 of these 312 inches (or a proportional amount of a smaller flow of canyon water) belong to lands lying in the north Palomares and Martin tracts; the remainder of the flow belongs to the Loup & Meserve tract, and the owners of a larger part of this share organized in 1897 as the Canyon Water Company of Pomona. This company controls 45½ per cent of the west-side San Antonio waters. The remainder of the Loup & Meserve owners maintain their original status of tenants in common.

The Canyon Water Company is capitalized at $312,000, divided into 31,200 shares with a par value of $10 each; 14,169.3 of these shares have been issued. The organization was effected by a number of the holders of canyon water rights, who deeded those rights to the company and received stock in exchange. In 1905 there were 87 stockholders. The majority of the stockholders held 125 shares per 10 acres, some held in excess of this number, and a few had but 100 shares. Each share represents one one-hundredth of a miner's inch when there is enough water flowing in the canyon to give the west-side irrigators their full quota of 312 inches. At other times it represents a smaller amount, whose value is proportional to the water available. The officers of the company state that the cost of the water to users is about 80 cents per acre per year, for maintenance and distribution.

During periods of diminished flow in the canyon the water derived from this source is supplemented by pumped water supplied by several private plants and by the Kingsley Tract Water Company, the Claremont Cooperative Water Company, and the C. W. Brundage Company. This accessory water is arranged for by individual irrigators and not through the company.

Official measurements of the waters of San Antonio Canyon are made three times yearly, on the first Mondays in July, August, and September, as a basis for the division of the waters. The share received by the Pomona irrigators as a result of these measurements from 1900 to 1905 is given in the following table:

Quantity of water, in miner's inches, delivered to Pomona irrigators from San Antonio Canyon, 1900–1905.

Year.	July.	August.	September.
1900	115	(?)	(?)
1901	312	257.07	213.55
1902	170.5	128.06	101.6
1903	312	271.05	214.77
1904	186.935	147.54	132.25
1905	312	312	312

DEL MONTE IRRIGATION COMPANY.

The Del Monte Irrigation Company is one of the four companies distributing water in the Pomona region, organized originally by the Pomona Land and Water Company. The organization of this branch was effected in February, 1887, with a capital stock of $400,000, divided into 40,000 shares with a par value of $10 each; 21,000 shares have been issued at the rate of 10 shares per acre, and the market value was reported in 1906 as $8 per share. There were at that time between 175 and 200 shareholders, all of whom were landowners under the system. Absentee ownership is not permitted.

From the Pomona Land and Water Company the Del Monte Company received the right to the natural flow from Del Monte ciénaga, one-fourth mile southeast of Claremont, and a right to develop water in a tract of 150 to 200 acres there. They also obtained from the same source the right to develop water in a 12-acre tract in

Martin ciénaga, one-fourth mile west of Claremont. In 1899 the company purchased an additional water right covering 68 acres in the Martin ciénaga. The price paid for this right was $25,000.

As early as 1886 artesian wells were bored in the ciénagas, and the number was gradually increased until about 28 in all had been sunk. The artesian flow, however, slowly decreased as a result of the increasing development and the succeeding dry years, and finally ceased in 1897. Thereafter the company depended entirely on pumping. The lift in 1905 was about 80 feet, but decreased markedly as a result of the three succeeding wet years.

In the Del Monte ciénaga the company operates a compressed-air plant, installed in 1899, from which seven wells within a few hundred feet of the plant were pumped in 1905. A Corliss air compressor operated by a 140-horsepower steam engine is used. Three wells in the Martin ciénaga have been pumped from this plant, but they were not in use in 1905. The air compressor, engine, and pipes are reported to have cost $15,000, and the output is given at 155 miner's inches. In addition to this central plant, one well in the Del Monte ciénaga is in use. A 40-horsepower motor and a Pomona deep-well pump are also used in the Martin ciénaga.

The water developed by the pumping plants is divided into four heads, prorated to stock and distributed at intervals of twenty-seven and one-half days by schedule through about 15 miles of 8 to 20 inch cement pipe owned by the company.

Annual assessments of 60 cents per share, or $6 per acre, cover the cost of operating and maintaining the system and interest on indebtedness.

IRRIGATION COMPANY OF POMONA.

The Irrigation Company of Pomona was organized by the Pomona Land and Water Company in July, 1886. It was capitalized at $245,000, divided into 24,500 shares with a par value of $10 each; 2,450 acres were included in the district, and lands in the tract were sold with 10 shares of water stock per acre. All of the stock has been issued. When the majority of the stock had been transferred to the purchasers of land in the district, the management of the company was turned over to them and the organization has since been operated as a mutual water company.

The original sources of water were San Jose Creek and the moist lands in which it rose and a number of artesian wells bored in these lands, which constituted the old artesian belt north of Pomona. About 45 wells have been bored at various times. With continued development and recurring dry seasons these sources of cheaper water failed, the artesian wells ceasing to flow from 1896 to 1899, and now the company depends entirely on pumped water. One large central pumping plant (No. 182, Pomona quadrangle) has been installed, and from this station, equipped with a 150-horsepower Corliss-Cross compound air compressor, 16 wells, the farthest half a mile away, are pumped. Smaller auxiliary plants have been used in the past, but were abandoned for the more economical concentrated system. It is estimated that the company has, in addition to the pumping plant, about 25 miles of iron and cement distributing pipe, varying from 6 to 20 inches in diameter. It owns one reservoir on Holt avenue, east of Pomona, whose capacity is 1,900,000 gallons. It also has the right to develop water on 200 acres of ground in the vicinity of the plant.

The company pumps for about seven months in the year, and produces from 200 to 250 inches continuous flow during this period. The water is divided into four heads, and each block of 100 shares of stock is given a twelve-hour run of one head monthly.

The expenses of maintenance, operation, and distribution are met by assessments on the stock, which amount to about 40 cents per share, or $4 per acre annually.

Of the 2,000 acres irrigated by this company, one-third is planted to citrus fruits and the remainder to diversified crops.

PALOMARES IRRIGATION COMPANY.

The Palomares Irrigation Company is one of the four companies organized by the Pomona Land and Water Company and succeeding to its rights. The organization was effected on February 23, 1887, with a capital stock of $60,000, divided into 6,000 shares at $10 per share. The water rights which the company owned were made appurtenant to 600 acres of land, and 10 shares of stock were sold with each acre.

The original source of the water used was a group of five artesian wells near the northern edge of the Pomona artesian area. These wells ceased to flow, with others in the same belt, in the late nineties. A pumping plant was then installed, and by its use from 40 to 80 inches of water are now procured from two wells (No. 291, Cucamonga quadrangle) and carried through a 22-inch main in a southeasterly direction to the Palomares tract, which lies between the territory covered by the Irrigation Company of Pomona and that served by the Del Monte Irrigation Company.

Pumping is usually begun in April and is continued thirty days per month and twenty-four hours per day until November. The water is distributed in full heads of 40 to 80 inches, each 100 shares receiving a twelve-hour run monthly.

The expenses involved in the maintenance of the plant and the distribution of the water are met by an annual assessment on the shareholders. For a number of years this assessment varied between a minimum of $3 and a maximum of $6 per acre annually.

CONSOLIDATED WATER COMPANY OF POMONA.

The Consolidated Water Company of Pomona was organized by Messrs. Becket, Brady, and Lathrop, and incorporated May 23, 1889, with a capital stock of $500,000, divided into 5,000 shares of $10 par value each.

The company serves the city of Pomona with water for domestic purposes. The supply is obtained from five pumping plants located in the old artesian basin about three-fourths of a mile south of North Pomona and from wells and tunnels in San Antonio Wash, one-fourth of a mile east of Indian Hill. Four of the five plants were installed in 1897 and 1898, and the fifth in the spring of 1904. Three of them are equipped with Addison-Lindsey deep-well lift pumps and two with centrifugal pumps. Electric power is used, and the combined capacity of the five plants is given at 200 inches. The cost is stated to be about $15,000.

In the years 1892-1896 land east of Indian Hill was purchased from Peter Fleming and James Becket, and a tunnel was driven into the wash in order to develop a gravity flow. This tunnel, starting at the surface near Claremont, is about 1 mile in length and reaches a depth of 120 feet at the upper end. Two wells have been sunk along it and now flow into it. A pipe line has also been laid along the lower part of the tunnel, and this section filled. The combined cost of the land, tunnel, and wells is given as $150,000.

The flow from this system varies with the season and the rainfall. During the winter months it reaches 160 inches, and is then ample for the city's needs. During the summer season, when the demands are heavy, the flow decreases, and an auxiliary supply is furnished by the pumping plants. Early in June, 1904, the flow from the wells and tunnel was reported at 70 inches, and during July of the same year, 54 inches. The city requires about 130 inches during the heated term, a large amount being applied to lawns, shrubbery, gardens, etc.

In 1905 the company reported 1,500 taps in active use. A part of the service is equipped with meters, of which there were then about 300, more than half of them owned by the consumers. Citizens may install meters at any time at a cost of $12, and pay thereafter for the actual amount of water used. Where meters are not used, the charges are regulated in great detail by city ordinance. An idea of the rates may be obtained from the following items: A charge of $1 per month is made for houses of five and six rooms, and 10 cents per month for each additional room. For irrigating lawns, 25 cents per month is charged throughout the year for 50 square yards or less, and one-fourth of a cent for each additional yard. Where meters are installed the following rates were established for the year beginning July 1, 1904: Minimum rate, 600 cubic feet or less, per month, $1; each additional 100 cubic feet to 2,500 cubic feet, 10 cents; each 100 cubic feet over 2,500 cubic feet, 8 cents. In its collecting and distributing system the company owns 6.6 miles of cement pipe, 8 to 20 inches in diameter; 9.4 miles of iron pressure pipe, 6 to 16 inches in diameter; 43.5 miles of iron pressure pipe, 2 to 5 inches in diameter; and 1 reservoir, capacity 1,000,000 gallons.

The cost of this system is about $90,000, while the total investment in lands, water rights, tunnels, wells, pumping plants, and distributing systems is given as $362,000.

KINGSLEY TRACT WATER COMPANY (LIMITED).

The irrigating enterprise known as the Kingsley Tract Water Company (Limited) was incorporated September 10, 1900, and capitalized at $53,625, divided into 5,362½ shares of a par value of $10 per share. About 2,900 shares have been issued to the 55 stockholders, and the water is distributed to these and to five tenants in common on the tract who have not come into the corporation.

The Kingsley tract is located northeast of Pomona, and is a part of the original Loup & Meserve tract, to which a portion of the San Antonio Canyon water is appurtenant. The Kingsley Tract Water Company is a mutual water-supply company, organized to distribute the stockholders' share of the canyon water and to develop and control a supply of domestic water. It has no control over the canyon water, but, with the the consent of the holders of canyon rights, distributes their water and collects assessments for maintaining the canyon system. When the flow from San Antonio Canyon apportioned to Pomona irrigators equals 312 inches, the Kingsley tract receives 52.65 inches, and the same proportion of a lesser flow. The company pumps domestic water and an auxiliary supply for irrigation from well No. 280 (Cucamonga quadrangle). Pumped water is used for irrigation only when necessary to keep the canyon head up to the regular amount. The well was sunk in 1884 by S. B. Kingsley, under contract with R. Cathcart, the owner of the property on which it is located. It was once artesian but it ceased flowing about 1892. By the terms of the contract Mr. Cathcart retained a two-fifths interest in the well and guaranteed a protection strip of 600 feet surrounding it.

The pumping plant, consisting of a 30-horsepower gas engine and centrifugal pump, was installed in 1898 or 1899. It has a capacity of 30 inches. The water is piped a distance of half a mile southeastward to a reservoir in the upper part of the tract, and thence is distributed to two smaller reservoirs. The large reservoir is 300 feet in diameter and 12 feet deep. Because of the large storage capacity of the reservoirs, night and Sunday irrigation is unnecessary. The distributing system consists of 6½ miles of irrigating pipe from 6 to 10 inches in diameter, and of about the same amount of iron pipe for domestic supply, from 1 to 4 inches in diameter.

Canyon water costs the irrigators about $2 per miner's inch per year, and pumped water is supplied at cost to the stockholders. About 350 acres are partially supplied with irrigating water, and domestic water is furnished to 55 families. The water is distributed in 25-inch heads, each acre being given a 102-minute run every two weeks. This is about equivalent to 1 miner's inch constant flow to 8 acres. For any excess over the regular head irrigators pay 2 cents per hour-inch.

Including the Loup & Meserve tract assessment of $104, the cost of operating and maintaining the system from January 1, 1904, to January 1, 1905, was $1,768. During the same period $2,546 was spent in development and new machinery. These charges are met by assessments on the stock.

MOUNTAIN VIEW WATER COMPANY.

The Mountain View Water Company is the successor of the old Fleming & Rohrer works, which consisted of several miles of pipe line and several hundred feet of tunnel driven into an outcrop of the old red alluvium that is exposed in San Antonio Wash about 1½ miles east of Indian Hill. With these earlier works the company acquired 480 acres of land, paying for the land and the developments $13,875. After acquiring the property the company sunk several wells and extended the tunnels to tap them. In July, 1896, a corporation was formed, the capital stock being fixed at $45,000, divided into 13,875 shares. This stock is not appurtenant to the land, but is held only by landowners.

In 1895 the gravity flow from the tunnel and wells reached 138 inches, but during the succeeding years the output diminished, and in 1899 two pumping plants were installed. These plants consist of 18- and 12-horsepower gas engines and centrifugal pumps. Their combined capacity is 45 miner's inches. During the winter season one well (No. 111, Cucamonga quadrangle) still flows a small amount into the tunnel. In the distributing system there are about 5 miles of 6- to 16-inch pipe.

The water developed is piped to the east a distance of 1½ miles and used on the Mountain View tract, about 1½ miles northwest of Upland, except for three days of each month, when it is conducted to the village of Claremont and used there for domestic supply. There are about 400 acres under irrigation in this system, and the water is distributed monthly in 30-inch heads on the basis of 1 inch to 10 acres. The cost of the water to the users is approximately $50 per inch, or $5 per acre annually.

CANYON RIDGE WATER COMPANY.

The Canyon Ridge Water Company is a small company which irrigates about 160 acres of land northwest of Upland, near the Mountain View Water Company's tract. It was incorporated March 12, 1900, and capitalized at $20,000, divided into 400 shares with a par value of $50 each. The stock is distributed among irrigators only. The company owns 10 acres of land in the upper part of the Ontario colony tract, on which a well has been sunk (No. 86, Cucamonga quadrangle) and a pumping plant installed. The plant consists of a 20-horsepower gas engine and a deep-well pump with a capacity of 25 miner's inches. About 2½ miles of 6-inch pipe are laid down the slope to the stockholders' lands, where the water is used. Distribution is effected in full heads in rotation at intervals of thirty days. The cost of the water to the users is given at about $60 per inch annually.

UPLAND WATER COMPANY.

The Upland Water Company is a corporation organized principally by stockholders of the Mountain View Water Company for the purpose of developing an auxiliary supply. The organization was effected in 1900, on the basis of a $30,000 capitalization divided into 300 shares. During the same year the company bought 30 acres of land, east of Upland and north of the Red Hills, sunk a well (No. 58, Cucamonga quadrangle), and installed a pumping plant. The original plant, consisting of a steam engine and Worthington pump, was replaced in 1905 by an electric motor and Pomona deep-well pump. The total investment in well and plant up to 1905 was about $1,200.

The capacity of the plant is reported as 40 inches. The water produced flows through about 26,000 feet of 10- and 8-inch cement pipe to the Mountain View tract, west of Upland, where it is distributed monthly in full heads to the stockholders, who are all irrigators. The cost of the water per annum is given as $10 per acre.

ORANGE GROVE TRACT WATER COMPANY.

The Orange Grove Tract Water Company was organized in 1889 by John E. Packard, who owned artesian water-bearing lands north of Pomona and about three-fourths of a mile from the easternmost point of the San Jose Hills. Mr. Packard sunk wells on this property, laid pipe lines and constructed reservoirs, and sold the rights to 14½ inches of water to the owners of the Vineyard tract of 80 acres, located in the present city of Pomona. A large part of the Vineyard tract has since been cut up into city lots. The water right of the

23 acres north of Pomona, on which the pumping plant is situated, was transferred by Mr. Packard to the Orange Grove Water Company, subject to the prior right of 14½ inches, made appurtenant to the Vineyard tract, as mentioned above.

Lands of the present Orange Grove tract, which lies south of the San Jose Hills and west of Pomona on Holt avenue, were sold with 10 shares of water stock per acre. Four thousand seven hundred and twenty shares were issued, covering 472 acres. There are 26 stockholders in the company, and all water developed except that belonging to the Vineyard tract is used by them. None is sold outside.

In the late nineties the artesian flow of the wells ceased, and about 1899 the company put in a pumping plant. This plant was installed for the purpose of supplying the Orange Grove company with domestic water and the Vineyard tract with the 14½ inches to which it was entitled. The plant consists of a 25-horsepower gas engine and a centrifugal pump. It is in operation throughout the year.

For irrigating purposes the company utilizes the water developed from the Alkire tunnel, which it has leased for a term of years. This tunnel, constructed by Josiah Alkire, is located close to the eastern point of the San Jose Hills and intercepts a part of the underflow around that point. The flow from this tunnel during August, 1905, was stated by Mr. French, the secretary of the company, to be 28 inches. The water developed is delivered to the Orange Grove tract and distributed in open ditches in 20-inch heads, each acre being given a run of three and three-fourths hours per month.

The combined cost of irrigating and domestic water during the four years from 1902–1905 is reported to have been about $5 per acre. This was covered by assessments on the stock.

CLAREMONT COOPERATIVE POWER COMPANY.

The Claremont Cooperative Water Company was organized in 1902, and 90 acres of land close to the foothills 2 miles northwest of Claremont were purchased. A well and pumping plant which had already been installed on the property were included in the purchase.

The lands on which the water is used lie just north of Claremont, and the water is delivered to them through about 2¾ miles of 12- and 8-inch cement pipe. The plant has a capacity of 30 miner's inches, but only about 60 acres are irrigated. No water is sold, the stockholders of the company using all that is pumped. The cost to them is reported to be about 1½ cents per hour-inch.

CITIZENS' LIGHT AND POWER COMPANY.

The Citizens' Light and Power Company was organized principally for the purpose of supplying the village of Claremont with domestic water. It was incorporated December 6, 1902, on a basis of 1,045 shares of stock of a par value of $10 per share, making a total capital of $10,450.

In April, 1903, 40 acres of land were purchased, high up on the slope above Claremont, about 1 mile from the foothills. Development was begun on this property the same season. A well was sunk and equipped with a 25-horsepower gas engine and Pomona plunger pump, an 8- or 10-inch main was laid to the village 2 miles below, and a reservoir with a capacity of 1,250,000 gallons was constructed. The plant will produce about 25 inches of water.

CHINO LAND AND WATER COMPANY.

The Chino Land and Water Company was organized in 1900, with a capital stock of $1,500,000, divided into 15,000 shares, the par value of each being $100. It succeeded to the holdings of Richard Gird, of Chino, these holdings including the greater part of the Chino ranch of 37,500 acres, with certain water rights and obligations. The company owns 14 or 15 flowing wells in the Chino artesian belt and two pumping plants.

The greater part of the water supply is furnished by a group of ten artesian wells, situated about 1¼ miles southwest of Chino. The water from this group is conducted for several miles in a southeasterly direction through an earthen ditch, to 600 or 700 acres of alfalfa land to which it is applied. The artesian flow is supplemented during the heated term by the water yielded by a pumping plant installed in 1903, about half a mile from the artesian group.

A second pumping plant, which supplies the village of Chino with domestic water, is situated about 1½ miles north of Pomona. This plant was installed in 1901, and a portion of its product is sometimes sold to outsiders. The well is one of the original Gird group, bored in the early eighties, and is reported to have yielded 80 inches of artesian water when first put down. There were 23 of these wells, drilled in the old Palomares ciénaga, and their reported total yield in the latter part of the decade between 1880 and 1890, is 300 or 350 inches. A pipe line with a capacity of 300 inches was laid by Mr. Gird from the wells to the vicinity of Chino, and his total investment in wells, pipe lines, and water rights is given as $200,000. The wells failed rapidly, however, and all ceased flowing in the years 1888 to 1891, and since Mr. Gird had agreed not to pump them, they have all been abandoned, except Nos. 280 and 287, Cucamonga quadrangle, over which pumping plants have been installed, and five or six others which are used by ranchers for domestic supply.

Some supplementary irrigation is accomplished on the Chino rancho by the use of waste waters from the beet-sugar factory at Chino. A group of 15 wells is pumped by compressed air for the use of the factory when it is in operation, and the waste is conducted south of Chino to lands on the north and south banks of Chino Creek.

SAN JOSE VALLEY SYSTEMS.

CURRIER TRACT WATER COMPANY.

The Currier Tract Water Company was incorporated in September, 1900, with a capital stock of $10,000, divided into 300 shares, whose par value is $33.33 each. There are at present 35 stockholders in the company. The company owns a well and pumping plant (No. 1, Pomona quadrangle), located a short distance west of Pomona. The plant consists of a 30-horsepower electric motor and centrifugal pump, which with the well cost $3,300. In addition to this plant, 1¼ miles of 10-inch cement pipe have been laid at an expense of $2,300, bringing the total investment up to $5,600. From this plant about 100 acres, principally in citrus fruits, are irrigated. It is reported by officers of the company that in July, 1905, an official measurement was made which indicated an output of 56 miner's inches from the plant. Costs are given as 85 cents per hour for pumping, while the total cost for operation and maintenance is from $550 to $560 annually.

A. T. CURRIER DEVELOPMENT.

The plant of A. T. Currier is a private enterprise, but its magnitude justifies a brief description. It consists of two wells located on the south bank of San Jose Creek about 1½ miles below Spadra, 560 feet of wooden flume, and 3¼ miles of 18- and 20-inch vitrified pipe, through which the water is carried along the foot of the hills south of San Jose Creek valley, the line terminating south of Lemon. The wells were sunk in 1902 to bed rock, which was reached at 80 and 115 feet, and the pipe line was laid during the same year, at a total expense of $15,400.

NORTH DITCH.

The old irrigation work formerly known as the Rowland & Foster ditch diverts water from the bed of San Jose Creek about 1½ miles northeast of Lemon. It follows the creek for one-fourth mile until it attains the elevation of the bottom lands, thence it passes due west across the valley for about 1 mile. The original ditch was built fifty or sixty years ago by the Spanish, but the present work, a dirt ditch throughout, was dug in 1885.

The water supply from the creek varies with the season, but is usually less than 40 miner's inches. The supply being lowest during the summer season, when irrigating water is most needed, it has been found necessary to supplement it by installing pumping plants, four of which are in operation. The water is used by the ranchers in the Lemon district on the north side of the creek, who irrigate from 100 to 125 acres. The entire head is distributed on the basis of one hour per acre each twenty-one days.

SOUTH DITCH.

About one-half mile below the diversion dam on San Jose Creek at the head of the combined north and south ditches the water is divided and half the flow is carried across the creek by flume and through the south ditch for about 2 miles in a southwesterly direction to the ranches which are served by it on the south side of the valley. Eleven individual ranchers are entitled to the water from this ditch, but as the flow is much too small for the acreage under cultivation, five or six pumping plants have been established to furnish an additional supply. The north and south ditches share the water of San Jose Creek at their common diversion point equally, each receiving, it is said, from 15 to 40 miner's inches. On the south ditch the full head is distributed on the basis of one hour per acre each twenty-five days.

LORDSBURG WATER COMPANY.

The Lordsburg Water Company was incorporated December 5, 1900, with a capital stock of $36,000, divided into 3,600 shares, with a par value of $10 each. Before the incorporation of the company its organizers had sunk wells, installed pumping plants, and laid a pipe line, at an expense of nearly $12,500. This property was exchanged for the stock, which is distributed among 35 shareholders. Three thousand five hundred shares were issued to the original owners, while 100 shares were retained as treasury stock. Later the company purchased some stock, so that in 1905 there were but 3,146 shares out.

The company owns three wells, two of which (Nos. 50 and 63, Pomona quadrangle) are in use. One of these wells is pumped by a 20-horsepower electric motor and the other by a 24-horsepower gas engine. The officers of the company report that from 50 to 60 miner's inches are developed by the two plants.

The distributing system includes about 5 miles of pipe line, nearly 3½ miles of which are in the main conduit, which extends northwestward from the pumping plants to San Dimas Wash and connects with the San Dimas, Covina, and Azusa irrigating systems. This conduit is 16, 12, and 10 inches in diameter, according to grade, and has a capacity of 120 to 140 miner's inches.

The cost of the water is given by the company's officers as about 1½ cents per hour-inch. Some stockholders have more water than they need, and sales are sometimes made to outsiders at a rate of 2½ cents per hour-inch.

There are 300 acres irrigated by the company, 40 acres south of the plant at Lordsburg and the balance below the pipe line between Lordsburg and San Dimas. Citrus fruits, alfalfa, and potatoes are grown.

LAVERNE LAND AND WATER COMPANY.

The Laverne Land and Water Company is a cooperative concern, organized and incorporated October 30, 1899. The capitalization is $25,000, divided into 500 shares whose par value is $50 each. The paid-up capital represents about one-half of the capital stock, 241½ shares having been issued.

At the time of the organization of the company 15 acres of land were purchased, and in 1900 two wells (No. 249, Pomona quadrangle) were sunk on this property, which lies 1½ miles northeast of Lordsburg. A 38-horsepower gas engine and two deep-well pumps, with a combined capacity of 55 inches, were installed, and 3 miles of cement, steel, and vitrified pipe were laid west and northwest from the plant for the delivery of water to the lands under irrigation. Both pumps are in operation only when the demand for water is large. The company reports that in 1903 one pump was used 1,087 hours and two pumps were used 1,402 hours, and that in 1904 one pump was used 650 hours and two pumps were used 3,170 hours.

A charge of 75 cents per hour is made for the output of both pumps, a rate of 1$\frac{4}{11}$ cents per hour-inch when the full head of 55 inches is delivered; and 40 cents per hour is charged for the output of one pump.

The water is used to irrigate 241 acres of citrus fruits. Each acre is given a two and one-half hours' run of a full head every thirty days, which is equivalent to a duty of 1 inch continuous flow to 5.3 acres when the full head of 55 inches is delivered. Water in excess of the regular supply is sometimes furnished to stockholders and to outsiders. In these cases a charge of 3 cents per hour-inch is made.

LEVERNE IRRIGATING COMPANY.

The Laverne Irrigating Company was incorporated March 17, 1902, with a capital stock of $25,000, divided into 500 shares. One acre of land with a water right to 5 acres and one-third interest in a well and pumping plant were acquired at Laverne, 1 mile east of San Dimas, from L. T. Gillett. The well had been sunk, the plant installed, and the pipe line laid in 1900. The pumping machinery consists of a 35-horsepower gas engine and centrifugal pump No. 4 and the distributing system of 2 miles of 10-inch cement pipe. One hundred acres of citrus fruits are irrigated, the water costing, it is reported, 1 cent per hour-inch. Water is distributed in full heads at thirty-day intervals.

SAN DIMAS IRRIGATION COMPANY.

In 1885 Messrs. Lyman, Allen, and Bixby, owners of riparian water rights in San Dimas Canyon, which they had purchased from Messrs. Brooks and Rogers, who made the original filings, laid an 8-inch pipe from the bed of San Dimas Creek out to the mesa lands east of the wash. During the same year they organized the San Dimas Land and Water Company, capitalizing it at $60,000, with 1,200 shares of of stock, 1,025 of which have been issued. The San Jose Ranch Company was organized in April, 1887, with a capital stock of $300,000, and controlled several thousand acres of land lying south of San Dimas Wash and extending westward to the Covina district. Its water rights covered the "Mud Springs" ciénaga, 1 mile southeast of San Dimas; the developments in Sycamore Flat Canyon, which then yielded 10 to 15 inches, but have since been abandoned; and certain claims on the flow of San Dimas Canyon based on the company's holdings of lands in the upper part of the canyon. In addition, it took possession of the water rights and development work of the San Dimas Land and Water Company, agreeing in return to furnish the latter company with 35 miner's inches constant flow.

Extended and expensive developments were at once undertaken. A 12- and 14-inch cement conduit was laid from the masonry forebay at the opening of San Dimas Canyon to the plain on the south, which formed a part of the large tract controlled by the Ranch Company. Sixteen 7-inch wells were sunk in the Mud Springs ciénaga, and a tunnel was driven to cut the wells at points varying from 20 to 30 feet below the surface. During the year of organization (1887) and the five years following, 3,300 feet of 3- by 6-foot tunnel were constructed in the ciénaga and a gravity flow was developed which is reported to have at one time reached a maximum of 77 miner's inches. From the canyon line and the Mud Springs ciénaga, 12 to 14 miles of 8- by 10-inch cement distributing pipe were laid to the ranch lands lying west of these sources. While these expenditures were being made, lands with water rights were sold, and by 1891 these rights, aggregating 160 inches, had been disposed of on the basis of $1,000 per inch. The company, unwisely managed from the start, had expended in various ways the money derived from the sale of the lands, but had made no adequate provision for obtaining the water which it had agreed to supply.

During the years 1891 to 1894 the flow from the only sources, San Dimas Canyon and Mud Springs ciénaga, gradually declined, and the company, unable to meet the demands of those who had bought water from it, offered to turn over to them its remaining assets, consisting of pipe and tunnel systems, various water rights, and $3,000 in cash. This offer was declined, and suit was instituted against the company to compel the delivery of the full quota of water according to contract; but a minority of the ranchers, believing that the company was exempt from penalty through the operation of the statute of limitations, withdrew from the suit, and after negotiations with the San Jose Ranch Company organized the San Dimas Irrigation Company on October 15, 1894. This company was capitalized at $160,000, divided into 1,600 shares, and to it the system of pipe lines and tunnels belonging to the Ranch Company was deeded. It was provided also that other purchasers of water rights from the San Jose Ranch Company should be allowed to join the new company within a year, the applicant to receive 10 shares of stock in the new organization for each inch of water purchased from the old.

Immediately after the formation of the San Dimas Irrigation Company, suit was brought to determine the ownership of the water from the Mud Springs ciénaga. In 1896 a decision was rendered, awarding this water, which had now fallen to 33 inches, according to precedence in use, thus leaving all except the first users without water. These first users shortly afterward organized the Ciénaga Land and Water Company.

The flow from the Mud Springs continued to decline, but the Ciénaga Company was unable to pump because the wells and tunnels belonged to the San Dimas Irrigation Company, and the latter company was unable to pump because the water belonged to the Ciénaga Company. This deadlock was broken by an agreement reached in 1898, whereby the San Dimas Irrigation Company agreed to install a pumping plant and deliver to the Ciénaga Land and Water Company, free of charge, 33 miner's inches, but reserved the privilege of turning the plant over to the Ciénaga Company at any time, allowing the latter company to pump the 33 inches at its own expense. In case this was done the San Dimas Irrigation Company was to be permitted to enter on the ciénaga lands and install an independent plant there.

In accordance with the terms of this agreement, the San Dimas Company installed a plant in 1898, and for three years delivered 33 miner's inches to the Ciénaga Company free of charge. At the end of this period, becoming dissatisfied, the San Dimas Company took advantage of the option in the agreement of 1898, and for one year the plant was operated at the expense of the Ciénaga Company, and but 33 inches developed. Finally, the latter company claiming that the cost of pumping under this arrangement was excessive, a contract was entered into, by the terms of which the San Dimas Company agreed to furnish the Ciénaga Company with 33 inches at a charge of three-fourths of a cent per hour-inch. This contract expired in December, 1907.

In 1895 it was discovered that a large body of water underlay San Dimas Wash, and from that time on many wells were sunk there and plants were established to supplement the supply in the surrounding districts. The San Dimas Irrigation Company, among others, entered this district in 1900, purchased land, put in a well, and erected a pumping plant. In 1904, because of the increased demand and the lowering of the water plane, a second, deeper well, 14 inches in diameter, was bored in the wash, and a 75-horsepower electric motor installed over it. The two wells there yielded 60 miner's inches after these improvements were completed.

In 1902 a well was sunk and equipped with pumping machinery on Bonita avenue, about one-fourth mile north of the Mud Springs ciénaga, and a considerable addition to the supply was thus obtained. At times, also, water has been purchased from outside systems when available at a reasonable price, and by these various means the supply has been kept equal to the demand. The only gravity water owned by the company is the tenth part of the flow of San Dimas Canyon, when the total is 37½ inches or less, and one-half of all in excess of this amount. Title to this share is a result of the compromise of January, 1905, which ended the long suit between the San Dimas Land and Water Company and other claimants to San Dimas Canyon water.

Stock of the San Dimas Irrigation Company is held exclusively by landowners, and the basis of distribution is 1 inch to 10 acres. Water rates are established yearly and are controlled by the cost of pumping. All improvement and maintenance charges are met by separate assessments.

In addition to the water owned by the company, about 150 inches of alien water produced by independent pumping plants is distributed through the San Dimas system, one-fourth cent per hour-inch being charged for this service.

Of the 3,000 acres irrigated in the San Dimas district, about 1,050 are supplied by the San Dimas Irrigation Company. Its assets are distributed about as follows: Pipe lines, 20 miles of 8- to 18-inch pipe, $30,000; wells and three pumping plants, $26,000; three pumping-plant sites, $2,300; land in San Dimas Canyon, $1,000; total, $59,300.

ARTESIAN BELT WATER COMPANY.

The Artesian Belt Water Company was incorporated August 14, 1897, and capitalized at $30,000, divided into 300 shares, which are distributed among 64 stockholders. This was one of the first companies organized in the San Dimas district for the purpose of developing and distributing pumped water, and it now owns and pumps the first well sunk there (No. 234, Pomona quadrangle). This well was bored in 1895 and the first plant was installed in 1896 by J. O. Enell. The original plant was a 30-horsepower boiler and duplex steam pump. Now a 54-horsepower engine is used. When the well was first bored water was encountered at 44 feet from the surface, but the water plane has since declined so that the lift is now much more than this.

In addition to the well and plant, the company owns 10 acres of land in San Dimas Wash and about 2½ miles of 12-inch cement pipe, the total estimated investment being $20,000. The distribution of the waters and the administration of the company are managed much as in the larger San Dimas Irrigation Company, several landowners being stockholders in both organizations.

NEW DEAL LAND AND WATER COMPANY.

The New Deal Land and Water Company was organized September 25, 1890, with a capital stock of $100,000, divided into 2,000 shares. It owns and operates a well and pumping plant (No. 236, Pomona quadrangle), 1 mile southeast of San Dimas, near the old Mud Springs ciénaga. The property on which the plant is located was purchased on the supposition that in the original deed from the San Jose Ranch Company no reservation had been made of the rights to the underground water in this vicinity, but after the transfer of the Ranch Company's rights to the San Dimas Irrigation Company, the latter organization claimed all underground waters in the vicinity of the springs, and the matter was carried to the courts. An agreement was finally reached, however, by the terms of which the New Deal Land and Water Company was given the right to sink and maintain its present well and was guaranteed a protection strip within a radius of 75 feet of the plant. The plant consists of a 12-horsepower gas engine and a No. 2 Fulton pump, and produces from 10 to 20 inches of water, with which about 100 acres of citrus fruits are irrigated.

FROSTLESS BELT WATER COMPANY.

The Frostless Belt Water Company was incorporated in April, 1901, with a capital stock of $10,000, divided into 1,000 shares, all of which have been issued. There are 13 stockholders, 10 of whom also own stock in the San Dimas Irrigation Company.

Soon after its organization the company purchased 20 acres of land at Laverne at a cost of $1,500, and not long thereafter a well was bored (No. 224, Pomona quadrangle) and equipped with a 30-horsepower gas engine and centrifugal pump. The plant is reported to yield 30 miner's inches. About 12,000 feet of 10-inch cement pipe have been laid for delivering the water to the lands of the stockholders southwest of San Dimas. The water is delivered in full heads of 25 to 30 inches at thirty-day intervals, at the rate of 1½ inches to 10 acres. Citrus fruits are raised. The company reports its investments as follows: Well and plant, $2,800; pipe line, $3,300; real estate, $1,500; total, $7,600.

SAN GABRIEL SYSTEMS.

HISTORY OF RIGHTS.

Wm. Ham. Hall states that the church fathers are reported to have taken water from San Gabriel River as early as 1821 for irrigation in the neighborhood of the San Gabriel mission. None of the present rights, however, date back to this earliest diversion, if it was actually made. The oldest of the present ditches is the Azusa, built in 1843 by Luis Arenas, owner at that time of the Azusa rancho. Eleven years later Andrés Duarte, who owned the Duarte rancho, built a second west-side ditch, to which some of the west-side irrigators claim their rights are traceable.

In 1852 or 1853 Mr. Dalton, who had meanwhile acquired the Azusa rancho, enlarged the east-side ditch, and disputes quickly arose, both as to the boundaries of the rancho and as to the ownership of the water carried in the enlarged ditch, settlers on the lower part of the ranch claiming a proportion of the waters carried in it. The period which intervened up to 1889 was one of much confusion. Disputes, litigation, and compromises were of repeated occurrence, the settlements which resulted from the latter often being of short duration. At the same time other settlers were taking up lands, and the interests involved became constantly greater and more complex. Slauson & Martz, from whose interests the Azusa Agricultural Water Company was later developed, secured possession of the Azusa ranch between 1880 and 1883, and in 1882 the Azusa Water Development and Irrigating Company, later the Covina Irrigating Company, began a tunnel for developing the underflow of the San Gabriel. This tunnel was completed in 1889, although the canal by which its waters were carried to a district east and south of that served by the older Azusa canal had been finished about 1885. The builders of this tunnel claimed to have developed by its construction 137 miner's inches of water, but the claim was disputed by the other companies interested in the San Gabriel flow. January 26, 1889, all of the claimants to San Gabriel River waters entered into an agreement, by the terms of which the water was divided among them, and perfected a scheme for controlling its distribution. For purposes of division the water was considered as consisting of 720 parts. When the total quantity is equal to or less than 1,700 miner's inches, each of the claimants gets a certain number of these parts, while the excess above 1,700 inches is divided somewhat differently. The number of 720ths that each claimant to the first

1,700 inches and to the excess receives, as agreed on in this compromise, is given in the following table:

Division of San Gabriel River waters.

[In seven hundred and twentieths.]

	First 1,700 inches.	Excess.
Azusa Water Development and Irrigating Co	72	231
Duarte Mutual Irrigation and Canal Co. and Beardslee Water Ditch Co	216	160
Azusa Land and Water Co	45	33
Azusa Agricultural Water Co	54	40
Kate S. Vosburg and Louise McNiel	27	30
"Old users," represented in part by the Azusa Irrigating Co. and Azusa Water Development and Irrigating Co	306	226

At the time of the compromise a committee of nine members, appointed by the several companies and associated irrigators, was given control of the water from its source to the point of division between the east-side and west-side users. Subcommittees, representing the respective interests, take charge of the water below this point.

This compromise served as a basis for the division of the water until the completion of the San Gabriel Power Company's conduit in 1898. After this conduit was built the power company claimed as salvage and was allowed one-tenth of all the canyon flow except 200 inches, which it was agreed to consider as developed by the Covina tunnel. This tenth was deducted proportionately from the share of each of the users under the compromise agreement of 1889, and on August 1, 1898, the salvage water was purchased from the power company by the Covina Irrigating Company for $66,500, and is now owned and used by the latter organization. The old apportionment, except as it is modified by this salvage agreement, is still in force. An account of the later developments is given in connection with the sketch of each of the companies that follows. The quantity of water available in the San Gabriel for all users and the fluctuations in the flow of the stream are shown in the accompanying tables, taken from the records of the United States Geological Survey. The minimum discharge of which there is record is 3 second-feet, reached in July and September, 1899, and in September, 1900; the maximum is the flood of March, 1905, with a discharge of 11,130 second-feet.

timated monthly discharge of San Gabriel River and canals at Azusa, Los Angeles County, 1896–1906.

[Drainage area, 222 square miles.]

	Discharge.			Total discharge.	Run-off.	
	Maximum.	Minimum.	Mean.		Per square mile.	Depth.
1896.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Acre-feet.*	*Sec.-feet.*	*Inches.*
nuary	51	26	37	2,275	0.17	0.20
bruary	61	36	41	2,358	.18	.19
arch	169	37	111	6,825	.50	.58
pril	91	40	54	3,213	.24	.27
ay	40	29	36	2,214	.16	.18
ne	27	13	19	1,131	.09	.10
ly	15	9	12	738	.05	.06
ugust	36	9	14	861	.06	.07
eptember	19	11	13	774	.06	.07
ctober	188	10	24	1,476	.11	.13
ovember	40	15	19	1,131	.09	.10
ecember	37	17	22	1,353	.10	.12
The year	188	9	34	24,349	.15	2.07
1897.						
January	147	25	57.9	3,617	.260	.292
February	1,713	64	344.8	19,146	1.553	1.579
March	1,765	294	465.6	28,623	2.097	2.418
April	370	201	294.4	17,519	1.325	1.478
May	196	94	145.0	8,851	.653	.748
June	91	54	67.8	4,033	.306	.341
July	52	27	38.1	2,343	.171	.197
August	34	22	26.4	1,613	.118	.136
September	23	18	20.7	1,226	.088	.098
October	1,640	22	90.5	5,564	.403	.465
November	34	31	33.3	1,860	.141	.149
December	34	28	30.5	1,875	.137	.158
The year	1,765	18	134.6	96,270	.604	8.059
1898.						
January	63	28	40	2,453	.18	.20
February	70	32	40	2,241	.18	.19
March	48	28	35	2,131	.16	.18
April	37	25.3	33	1,950	.15	.17
May	83	25.0	36	2,223	.16	.19
June	30	14.5	19	1,159	.09	.10
July	14	9.0	11	672	.05	.06
August	9	5.0	7	456	.03	.04
September	10	6.1	8	467	.04	.04
October	10	7.5	9	533	.04	.05
November	11	8.0	10	580	.04	.05
December	18	11.7	14	832	.06	.07
The year	83	5.0	22	15,697	.10	1.34
1899.						
January	33	15	23	1,414	.104	.120
February	28	20	22	1,244	.102	.106
March	40	18	26	1,623	.119	.137
April	28	16	21	1,262	.096	.107
May	17	12	14	842	.062	.071
June	22	5	10	565	.043	.048
July	4	3	4	221	.016	.018
August	6	4	5	295	.022	.025
September	6	3	4	220	.019	.021
October	26	4	11	709	.050	.058
November	24	10	14	847	.064	.071
December	39	16	20	1,247	.091	.105
The year	40	3	14.5	10,489	.065	.887
1900.						
January	89	22	32	1,968	.14	.16
February	23	18	20	1,111	.09	.09
March	30	16	20	1,230	.09	.10
April	26	13	17	1,012	.08	.09
May	86	16	37	2,275	.17	.20
June	22	8	15	893	.07	.08
July	10	4	6	369	.03	.03
August	5	4	4	246	02	.02
September	6	3	4	238	.02	.02
October	6	4	5	307	.02	.02
November	5,200	5	186	11,068	84	.93
December 1-16	53	31	40	1,269	.18	.11
The year	5,200	3	32	21,986	.15	1.85

Estimated monthly discharge of San Gabriel River and canals at Azusa. Los Angeles County, 1896–1906—Continued.

[Drainage area, 222 square miles.]

	Discharge.			Total discharge.	Run-off.	
	Maximum.	Minimum.	Mean.		Per square mile.	Depth.
1901.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Acre-feet.*	*Sec.-feet.*	*Inches.*
January	1,450	28	169	10,391	.76	[illegible]
February	2,605	137	680	37,765	3.06	3.19
March	440	135	221	13,569	1.00	[illegible]
April	130	95	110	6,545	.50	[illegible]
May	272	83	121	7,440	.55	[illegible]
June	93	41	63	3,749	.28	[illegible]
July	41	24	30	1,845	.14	[illegible]
August	27	15	20	1,230	.09	[illegible]
September	20	15	17	1,012	.08	[illegible]
October	122	15	24	1,476	.11	[illegible]
November	50	29	32	1,904	.14	[illegible]
December	30	26	27	1,660	.12	[illegible]
The year	2,605	15	126	88,606	.57	[illegible]
1902.						
January	51	24	28	1,722	.13	[illegible]
February	120	38	37	2,055	.17	[illegible]
March	378	63	99	6,087	.45	[illegible]
April	99	48	66	3,927	.30	[illegible]
May	48	30	39	2,398	.17	[illegible]
June	29.5	13.5	20	1,190	.09	[illegible]
July	17	7.5	11	676	.05	[illegible]
August	8.5	6	7	430	.03	[illegible]
September	6	4.5	5	298	.02	[illegible]
October	10.5	5.5	7	430	.03	[illegible]
November	80	7.5	19	1,131	.09	[illegible]
December	68	16	32	1,968	.14	[illegible]
The year	378	4.5	31	22,312	.14	[illegible]
1903.						
January	2,999	22	148	9,100	.67	[illegible]
February	203	61	102	5,665	.46	[illegible]
March	1,417	57	257	15,802	1.16	[illegible]
April	5,892	267	792	47,127	3.57	[illegible]
May	355	125	217	13,343	.98	[illegible]
June	125	62	95	5,653	.43	[illegible]
July	58	35	43	2,644	.19	[illegible]
August	35	24	29	1,783	.13	[illegible]
September	34	21	25	1,488	.11	[illegible]
October	32	20	24	1,476	.11	[illegible]
November	26	22	24	1,428	.11	[illegible]
December	26	22	24	1,476	.11	[illegible]
The year	5,892	20	148	106,985	.67	[illegible]
1904.						
January	28.2	23	24.4	1,500	.11	[illegible]
February	438	23	47.7	2,744	.21	[illegible]
March	1,130	35	110.8	6,813	.50	[illegible]
April	120	57	89.7	5,337	.40	.45
May	104	37	66.5	4,089	.30	[illegible]
June	38	17.5	25.5	1,517	.11	[illegible]
July	18	11	14.0	861	.06	[illegible]
August	29	9.5	12.9	793	.06	[illegible]
September	13.5	7.5	10.8	643	.05	[illegible]
October	15.5	9.0	12.0	738	.05	[illegible]
November	14.5	11.0	12.8	762	.06	[illegible]
December	48	14.7	16.9	1,039	.08	[illegible]
The year	1,130	7.5	37	26,836	.17	[illegible]
1905.						
January	108	18.5	36.6	2,251	.16	[illegible]
February	3,010	34	466	25,880	2.10	2.19
March	11,130	142	1,222	75,140	5.50	[illegible]
April	474	206	329	19,580	1.48	[illegible]
May	540	193	278	17,090	1.25	1.44
June	182	63	139	8,271	.63	[illegible]
July	109	56	83	5,103	.37	[illegible]
August	55	33	42.8	2,631	.19	[illegible]
September	35	28	31.4	1,869	.14	[illegible]
October	32	27	28.8	1,771	.13	[illegible]
November	97	29	44.7	2,660	.20	[illegible]
December	50	37	40.1	2,466	.18	[illegible]
The year	11,130	18.5	2,284	164,700	1.03	[illegible]

Estimated monthly discharge of San Gabriel River and canals at Azusa, Los Angeles County, 1896–1906—Continued.

[Drainage area, 222 square miles.]

	Discharge.			Total discharge.	Run-off.	
	Maximum.	Minimum.	Mean.		Per square mile.	Depth.
1906.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Acre-feet.*	*Sec.-feet.*	*Inches*
January	441	36	68.1	4,190	.307	.35
February	92	47	68.1	3,780	.307	.32
March	9,430	56	2,160	133,000	9.73	11.22
April	1,110	321	578	34,400	2.60	2.90
May	1,110	251	342	21,000	1.54	1.78
June	364	204	262	15,600	1.18	1.32
July	295	97	155	9,530	.698	.80
August	93	57	72.8	4,480	.328	.38
September	55	42	47.7	2,840	.215	.24
October	42	38	39.8	2,450	.179	.21
November	47	37	40.4	2,400	.182	.20
December	1,600	45	188	11,600	.847	.98
The year	9,430	36	335	245,000	1.51	20.70

AZUSA IRRIGATING COMPANY.

The Azusa Irrigating Company was organized and incorporated August 23, 1886, by a part of the Azusa "old settlement" irrigators. The company was capitalized at $60,000, divided into 4,000 shares with a par value of $15 each, but the capital has since been increased to $180,000. Of the 12,000 shares, 10,865 have been issued and are distributed among 199 shareholders. They are reported to have a market value of about $35 each. The basis of the distribution is three shares to the acre. Delinquent stock reverts to the company and may be reissued, but only to lands within the Azusa water district established by the compromise of 1889. This district includes 5,508 acres, of which 4,043 are covered by the Azusa Irrigating Company and 1,465 acres are under contract by the Covina Irrigating Compay.

Water is prorated to stock and is distributed in 100-inch heads, which during times of abundant supply are given twelve-hour runs to each 10-acre tract in turn. When the supply becomes short, the time in each run is reduced.

The company owns the Azusa ditch, the oldest of the east-side canals, and other canals and pipe lines aggregating about 40 miles. The main canal is about 3 miles in length from the Azusa ice house, where the Covina and Azusa waters are divided, and this main line is extended 1½ miles beyond the terminus of the canal by a 30-inch vitrified pipe. The main distributing lines consist of 10-, 12-, and 14-inch cement pipe, according to grade, and are designed to carry 120 miner's inches. A reservoir with a capacity of 6,500,000 gallons and capable, therefore, of impounding a continuous flow of 800 miner's inches for fifteen hours, forms a part of the system. It was built in 1893 at a cost of $13,000.

In addition to the rights of the San Gabriel waters and the distributing system mentioned above, the company owns 40 acres of land in San Dimas Wash. Wells were sunk on this property, a pumping plant was installed, and a pipe line 4½ miles in length was laid due west to the main ditch, but the plant was sold later. Nevertheless, much pumped water is used in the district during seasons when the supply of gravity water is low. The Glendora and Azusa Water Company supplies the upper part of the district, and the lower part receives water from the Irwindale wells, operated by the Irwindale Land and Water Company, the Orange Avenue Water Company, and the Cypress Avenue Water Company. The majority of the stockholders in these subsidiary companies are also stockholders in the Azusa Irrigating Company.

Water rates are collected on the basis of a sliding scale, charges varying from $1.20 in February to $5.40 in July, August, and September for a twelve-hour run of a 100-inch head. The winter and spring charges, when water is abundant, are intended to be only nominal and merely to cover the zanjero's fees.

COVINA IRRIGATING COMPANY.

The Azusa Water Development and Irrigating Company, whose name was changed later to the Covina Irrigating Company, was incorporated May 20, 1882, capitalized at $5,000, and 6,667 shares of stock were issued at a par value of 75 cents per share. As its works were extended the capital stock of the company was increased at various times, and finally, in October, 1886, it was organized on its present basis of 10,000 shares at $50 per share.

The original company was organized to develop the underflow of San Gabriel Canyon and furnish a water supply for summer irrigation when the surface flow is low. In fulfillment of this purpose the tunnel, which cuts through two rock points in a crooked part of the canyon, about a mile above its mouth, was undertaken in 1882 and completed in 1889. This work, about 2,200 feet in length, in connection with a bed-rock dam below its upper section, delivers about 137 miner's inches, which amount, it was claimed by the promoters of the enterprise, had been developed by their work. This position was contested by other companies holding rights to San Gabriel waters, and the matter was not settled until in the compromise of 1889 one-tenth of the combined natural and developed flow of the canyon, so long as this was 1,700 inches or less, was awarded to the Covina Company.

On August 1, 1898, the salvage, which had been construed as belonging to the San Gabriel Power Company, whose canal above the power house had effected the saving, amounting to one-tenth of the total flow at the point of diversion 7 miles above the power house, after 200 inches had been deducted, was purchased by the Covina Company for $66,500. In addition to water from these two sources the company receives the share of certain old users, whose interests aggregate about one-tenth of the flow of the canyon, and delivers this water to its owners at the rate of about 1 inch to 8 acres. About 1,465 acres are irrigated under this contract. When the total flow of the San Gabriel is 2,000 inches, the Covina Irrigating Company receives a total of 593.72 inches, consisting of company water, 210.7 inches; San Gabriel power water, 180 inches; and "old users" or contract water, 203.02 inches.

Like many other irrigating enterprises previously dependent on mountain water for a supply, the Covina Irrigating Company found during the dry years of the late nineties that its gravity water was insufficient for its needs and it was forced to resort to pumping. With this contingency in view, 104 acres of land one-half mile south of Lordsburg had been purchased for $20,000 on November 25, 1896. During 1898 and 1899 ten wells were bored on this property, a 100-horsepower steam engine and compressor were installed (Nos. 200–201) at a cost of $14,000, and a 12- and 16-inch pipe line was laid westward 6 miles from the pumping plant to the main canal.

March 21, 1899, 40 acres of water-bearing land were bought in San Dimas Wash for $10,000. A well (No. 242, Pomona quadrangle) was sunk shortly afterward on this property, equipped with a steam and air plant at a total cost of $5,000, and a 16-inch pipe line was laid to connect this plant with the system. Later in 1899 several hundred acres additional were purchased in San Dimas Wash at an outlay of about $15,000. In 1900 a plant (No. 230, Pomona quadrangle) was installed on this property, and connections with the system were effected. A further extension of the pumping system was made in 1904 by the addition of a small gasoline engine as an auxiliary to the Lordsburg plant.

The volume of this pumped water varies with the seasons, since it is used only to augment the canyon flow. During the summer of 1904, following an unfavorable winter, San Gabriel River was very low, and the pumping plants were in operation for a longer period than during any previous season. The following statement summarizes these operations:

Operations of Covina Irrigating Company's pumping plants, 1904.

No. of plant.	Time operated.	Average yield.	Cost per hour-inch.
	Days.	*Inches.*	*Cents.*
200-201	224	90	1.4
200-201, gasoline adjunct	12	30	
230	139	25	2.13
242	115	37	2.65

During this season the volume of pumped and canyon water delivered by the Covina Irrigating Company was as follows: Company water, 66,483 hour heads (25 miner's inches), equivalent to 189.75 inches continuous flow; contract water, 24,375 hour heads, equivalent to 69.6 inches continuous flow; alien water, 4,432 hour heads, equivalent to 12.6 inches continuous flow.

The company owns 5½ miles of the original Azusa Water Development and Irrigating Company's canal, built in 1885 at a cost of $40,000. This canal is cement lined, averages 4 feet in depth, and is from 4 to 8 feet wide. It ends in a 15,000,000-gallon cement-lined reservoir, located about 1 mile northeast of Covina. This reservoir was built in 1887 at a cost of $13,000. In addition to the canal and reservoir, which form the main artery and regulator of the system, there are nearly 1,200 feet of 16-inch, over 60,000 feet of 12-inch, 44,200 feet of 10-inch, and 1,500 feet of 8-inch cement mains and distributing pipe.

The stock of the Covina Irrigating Company is practically all held by landowners, although it is not appurtenant to the land and there is no provision in the charter prohibiting outside ownership. Nor is there any restriction as to the number of shares that may be acquired per acre, the irrigator being free to purchase as much stock as he thinks he needs. It is said that this condition occasionally results in abuse, and that a certain amount of trickery sometimes appears in the practical operation of the system. For instance, a part of the water stock pertaining to a given tract may be sold, leaving the property without a sufficient water supply. The land with the remaining stock may then be sold to some outsider who is not familiar with local conditions and who believes that he is buying enough water to irrigate his acreage.

All of the company water, gravity and pumped, is apportioned to stock, independent of acreage, and is distributed in rotation by schedule. Usually in midsummer a 25-inch head is given a six-hour run to each 10 acres, but a 50- or 100-inch head may be used at the option of the irrigator. The regular charge for delivery is at the rate of $2.50 per 100 inches for a twelve-hour run, and the annual water charge therefor is from $1.25 to $1.50 per acre. In addition to this, stock is assessed for whatever expense there may be in operating and maintaining the system in excess of the water receipts. This annual assessment varies from $2 to $3.50 per share. In 1904 water collections amounted to $5,126 and stock assessments to $30,000. There are 243 stockholders in the company, and water is delivered to about 350 irrigators, including the contractors. Many of the latter are stockholders also.

There are about 3,000 acres under the Covina system, but as an indefinite part of this acreage is supplied with water from outside sources, it is not possible to state just the area irrigated by the Covina Company. The Citrus Belt Water Company supplies accessory water to the upper part of the district, between Glendora and Azusa, and the Columbia Water Company to the lower lands in the neighborhood of Covina. Most of the stockholders in these companies hold stock in the Covina Irrigating Company also.

AZUSA AGRICULTURAL WATER COMPANY.

In 1887 J. S. Slauson, J. D. Bicknell, and others, owners of 4,500 of the 5,000 acres in the Azusa ranch, combined these lands and the waters belonging thereto, forming an organization under the name of the Azusa Land and Water Company. The next year the Azusa Agricultural Water Company was organized with 6,000 shares, of a par value of $100 each, and the water rights of the Azusa Land and Water Company were transferred to it. Two shares of stock in the water company were conveyed with each acre of land sold by the Land and Water Company.

The rights of these companies, which depended on those of Mr. Dalton, former owner of the Azusa ranch, were not definitely settled until by the compromise of 1889 they were awarded $\frac{99}{720}$ of the total San Gabriel flow up to 1,700 inches, and $\frac{73}{720}$ of the excess over this amount. This apportionment, like that of all the other claimants to San Gabriel waters, has since been altered by the award of one-tenth of these waters to the San Gabriel Power Company as salvage.

The San Gabriel Canyon waters of the Azusa Agricultural Water Company reach the Azusa district through the Azusa canal, which carries the water of the Azusa Irrigating Company also. The division is effected at a point about one-quarter of a mile southeast of the Azusa ice house, where the water of the Azusa Agricultural Water Company enters its own system. This system, by means of which 900 acres, chiefly in oranges and lemons, are irrigated, includes about 4 miles of open cement flume 12 by 14 inches, and 4 miles of 8-, 10-, and 14-inch cement pipe. A reservoir with a capacity of 1,000,000 gallons has been built at a cost of $2,000.

The canyon water of this system has been supplemented by pumped water, a well (No. 255, Pomona quadrangle) just within the mouth of San Gabriel Canyon having been sunk in 1901 and equipped with a 30-horsepower electric motor at a total cost of $5,000. The water is pumped into the main canal and is taken out with the rest of the Azusa Agricultural Water Company's water, one-quarter of a mile southeast of the Azusa ice house. About 50 miner's inches are reported to be developed by this well. During the spring of 1905 another well was sunk in the wash, about one-half mile below the mouth of the canyon, and 8,440 feet of 16- and 20-inch cement pipe were laid to connect with the Azusa irrigating ditch above Azusa.

The water supply of this company is prorated to stock and distributed at intervals of four to six weeks. The domestic supply for the city of Azusa is taken from the Azusa Agricultural Water Company's share of the San Gabriel water, and in addition 39 families outside the town are supplied with domestic water.

CITRUS BELT WATER COMPANY.

The Citrus Belt Water Company was organized in 1900 by a number of irrigators in the district south and southwest of Glendora. They were owners of stock in the Covina Irrigating Company, who desired to supplement their portion of canyon water with pumped water. The capital stock of the new company was fixed at $35,000, divided into 500 shares with a par value of $70. Two hundred and thirty-five shares have been issued.

In the fall of 1900 the company purchased 42½ acres in San Dimas Wash, 5 or 6 miles from the lands of the stockholders, sunk a well, and installed a pumping plant. This plant consists of a 105-horsepower steam engine and centrifugal pump, and its capacity is given as 75 miner's inches. The cost of installation was $4,000. About 8 miles of 10- and 12-inch cement pipe, costing $9,000, and a reservoir costing $1,050 constitute the main distributing system. The water is delivered to each irrigator in turn in 25- or 50-inch heads, at intervals of two weeks. It costs the stockholders, of whom there are 43, about 2½ cents per hour-inch. The investments of the company is summarized by its officers as follows:

Property of Citrus Belt Water Company.

Land, 43½ acres	$10,000
Cement pipe, 3 miles 12-inch, 5 miles 10-inch	9,000
Pumping plant, 105 horsepower	4,000
Reservoir	1,050
	24,050

COLUMBIA LAND AND WATER COMPANY.

The Columbia Land and Water Company, like the Citrus Belt Company, was organized by stockholders of the Covina Irrigating Company to supply pumped water to their lands at times when the canyon flow is low. The company was organized in April, 1899, and capitalized at $60,000, divided into 600 shares. Twenty acres of land were acquired in San Dimas Wash, with two wells and pumping plants (No. 241, Pomona quadrangle) and several miles of pipe line. Each pumping plant is equipped with a 30-horsepower gas engine and centrifugal pump. The initial combined capacity of the two is given as 50 inches, which falls to 30 inches as the water level declines with continuous pumping. The pumps are operated twelve hours per day and about five months of each year, from June until the beginning of the rains. A full head is used in irrigating and is charged for at the rate of $1 per hour, which, inasmuch as the amount of water in a head varies, equals 2 to 3 cents per hour-inch. The distributing system includes a reservoir built in 1904, and about 5 miles of 8- to 12-inch main, extending from the wells to the reservoir, 1 mile northeast of Covina.

The company's investment is as follows:

Property of Columbia Land and Water Company.

Wells and pumping plants	$3,700
Pipe lines, 5 miles	5,000
Reservoir	2,500
Real estate	1,000
	12,200

WESTERN WATER AND POWER COMPANY.

The predecessor of the Western Water and Power Company, the Glendora Water Company, was organized in 1887, with a capital stock of $62,500, divided into 1,250 shares, the par value being $50 each. Lands were acquired at once in Big Dalton Canyon, which gave to the company the control of all of this canyon and its water rights except 120 acres with the water pertaining thereto. This amount belonged to the Mountain Base Water Company until 1888, when it was purchased by the Glendora Water Company for $5,000, thus placing in the latter company complete control of Big Dalton Canyon and all its water rights. From 1887 to 1898, inclusive, the capital stock of the company was paid up in full and the money expended in improvements and betterments, approximately as follows:

Expenditures of Glendora Water Company.

Lands and riparian rights	$10,000
Reservoirs, 3; combined capacity, 2,500,000 gallons	8,000
Puddle dam in Big Dalton Canyon	8,000
Tunnel (1,200 feet) in Big Dalton Canyon for developing water	14,000
Supply pipe (8-, 10-, and 12-inch) for conducting waters from Big Dalton Canyon to Glendora and vicinity	10,000
Distributing pipe (12 miles, 1½- to 4-inch) for distributing water in Glendora	13,000
	63,000

During the trying years from 1897 to 1900 the Glendora Company, like the majority of southern California water companies, found its gravity supply insufficient to maintain the acreage already under irrigation, and it became necessary to resort to pumping. In 1901 160 acres were purchased in San Dimas Wash, in which several successful wells had already been located; two 12-inch wells (Nos. 232 and 233, Pomona quadrangle), each about 500 feet deep, were bored, and a 250-horsepower pumping plant was installed and connected with a No. 6 centrifugal pump in each well. A 14-inch pipe line was then laid from the wells to connect with the Dalton Canyon line, 5 miles away. The wells produce about 125 miner's inches. These additions to the system were effected by means of a loan of $41,500 negotiated in 1901, the company's property serving as security. The details of the expenditures are about as follows: Land, $20,000; wells, $5,000; pumping plant, $10,000; supply pipe, $7,000. From 1901 to 1904 about $20,000 additional was expended on the pumping plant and branch pipe lines, and a considerable reduction was made in the company's indebtedness. As the expenditures and the value of the property owned exceeded the capital stock of the Glendora Water Company by a large amount, a reorganization seemed desirable. This was effected in April, 1904, by a sale of the company's property to the Western Water and Power Company, of Chicago, Ill. The capital stock of the newer organization is fixed at $100,000, divided into 1,000 shares whose par value is $100 each.

Since this sale the Western Water and Power Company has bought out the Alosta Water and Development Company, consisting of lands that control the water rights of Little Dalton Canyon and a system of pipe lines from this canyon to Alosta, just south of Glendora. Thus the present organization owns all the gravity water from Big and Little Dalton canyons and the pumping plant in San Dimas Wash. The gravity water is used when it is available; during favorable years it is sufficient to supply the system until after June 1, and yields a portion of the water required until a later date. The pumps are operated during the summer and fall.

Water rights have been sold to purchasers at 2½ and 4 cents per hour-inch. The rights have no relation to the lands, except that many of the large stockholders in the company are also large landowners under the Glendora system, so that their interests are identical.

GLENDORA-AZUSA WATER COMPANY.

The Glendora-Azusa Water Company was incorporated August 29, 1898, and capitalized at $48,450, divided into 484½ shares with a par value of $100 each. In 1898 170 acres of land were purchased in San Dimas Wash, at a cost of about $6,000. In 1900 a pumping plant was installed, and in 1902 a second well was sunk and equipped with pumping machinery. Centrifugal pumps are used in both wells (No. 231, Pomona quadrangle), a 75-horsepower motor running one and a 100-horsepower motor the other. The water is conducted from the wells through 10 or 11 miles of concrete pipe line to the lands served, lying west of Glendora, and distributed there. The system also includes one small reservoir with a capacity of about 200,000 gallons.

This is one of the systems developed partly to supplement the flow from San Gabriel Canyon, a part of the lands served lying below the Azusa and Covina canals and receiving gravity water from them. The pumping season of the Glendora-Azusa Company, therefore, varies with the supply of gravity water, being shortest during seasons of greatest rainfall. From 500 to 1,000 acres are wholly or partially supplied with water, which is distributed at a cost of 2½ cents per hour-inch. The average output during the season of 1905 is given at something less than 100 inches.

IRWINDALE WATER COMPANIES.

In the lower part of the Azusa water district, near Irwindale, three companies have been organized and pumping plants have been installed to develop underground water to serve as a supplement to the San Gabriel Canyon water. These are the Orange Avenue Land and Water Company, the Irwindale Land and Water Company, and the Cypress Avenue Land and Water Company.

ORANGE AVENUE LAND AND WATER COMPANY.

The Orange Avenue Company was organized in September, 1902, with a capital of $4,500, divided into 300 shares, distributed among 18 stockholders, all landowners. The plant consists of a well (No. 82, Pomona quadrangle) equipped with a 75-horsepower steam pumping plant. There is no pipe line, water being distributed to the stockholders directly or through the system of the Azusa Irrigating Company. The water costs the stockholders 1.55 cents per hour-inch, and is sold to outsiders for 3 cents per hour-inch. Distribution is effected in 25-, 50-, or 100-inch heads, as desired. About 380 acres are reported to be under irrigation.

IRWINDALE LAND AND WATER COMPANY.

The Irwindale Land and Water Company was incorporated September 19, 1899, and capitalized at $5,000, divided into 500 shares, which are distributed among 21 stockholders. Soon after organization one-tenth of an acre of land was purchased close to Irwindale, a well was sunk (No. 83, Pomona quadrangle), and a pumping plant was installed upon it. The plant consists of a 30-horsepower steam engine and Worthington pump, and its capacity is given as 60 inches. The output is pumped into the Azusa Irrigating Company's system and distributed through it. Distribution is effected in full heads, each share of stock being entitled to one hour's run monthly. The charge to stockholders is 2 cents per hour-inch, and to outsiders 3 cents per hour-inch. The water is used only to supplement the cheaper canyon water.

CYPRESS AVENUE WATER COMPANY.

The Cypress Avenue Water Company was organized in 1900 with a capital stock of $10,000, divided into 400 shares having a par value of $25 each; 202 shares have been subscribed for. The company operates a plant (No. 92, Pomona qadrangle) equipped with a 125-horsepower steam engine and centrifugal pump, reported to produce 113 inches of water. An independent steel pipe line, 1,300 feet in length, is also owned by the company. About one-half of the water is pumped into the Azusa Irrigating Company's system and the other half is distributed directly to stockholders. The water costs stockholders 1 cent per hour-inch; a charge of 3 cents per hour-inch is made to outsiders. All the members are stockholders in the Azusa Irrigating Company.

VINELAND IRRIGATION DISTRICT.

The Vineland irrigation district was organized in 1891, to include 4,000 acres in the vicinity of Vineland, just east of San Gabriel Wash. It claimed certain rights to San Gabriel Canyon waters, and these rights were sold with the land in the district. In the disputes which followed, however, the rights claimed by the district were given up in return for the installation of a pumping plant by the San Gabriel Power Company on a well which had been sunk by the Vineland irrigators on their tract. Such irrigation as is carried on in the district now depends on developed water from this plant, and inasmuch as the soil is sandy and porous and requires a large amount of water, and pumped water costs from 2 to 2½ cents per hour-inch, it has not been found practicable to irrigate vineyards or deciduous fruits. About 120 acres of citrus fruits, walnuts, and vegetables are irrigated, and perhaps 80 acres more are under cultivation.

An open stone ditch about 12 by 18 inches in size extends from the mouth of San Gabriel Canyon to a point 1 mile north of this district. This ditch catches some water from the Azusa ice-house waste ditch in winter, and this water is sometimes used by the Vineland irrigators.

DUARTE WATER COMPANIES.

RIGHTS.

The Duarte district is supplied with water by the Duarte Mutual Irrigation and Canal Company and the Beardslee Water Ditch Company. The upper part of the tract, consisting of about 1,000 acres, principally in citrus orchards, receives water from the former company. This area lies close to the base of the San Gabriel Mountains, on the sloping bench lands northwest of San Gabriel Wash. It extends from northeast to southwest a distance of 3 miles, and ranges in width from three-eighths of a mile at the eastern extremity to 1¼ miles on the west. The Beardslee Water Ditch Company serves about 400 acres of alluvial lands lying above San Gabriel Wash and adjoining the Duarte district on the west and south.

It is claimed that the rights of the Duarte irrigators to San Gabriel River water date back to 1854, when Andrés Duarte, the owner of the rancho, constructed a ditch and diverted a part of the San Gabriel flow to the west side. In 1859 or 1860, N. Beardslee acquired a part of the Duarte ranch by purchase, with the right to take water from the river for irrigation, and in the later year constructed a branch ditch to the lower Duarte neighborhood.

In 1872 Alexander Weil succeeded to the ownership of the Duarte interests, subdivided a part of the ranch, and sold off numerous small parcels along the upper part of the ranch, close to the base of the mountains, with rights to the Duarte ditch waters. In 1875 Mr. Beardslee sold several small tracts with rights to his share of river water, and in 1881 the purchasers of his lands and water rights organized and incorporated the Beardslee Water Ditch Company. In February, 1882, the property owners who had succeeded to the water rights of the Duarte ditch incorporated the Duarte Mutual Irrigation and Canal Company. For several years the flow through the joint ditch was divided equally between the two companies, but when the present works were built (1882–1887) and paid for by arrangement between the two companies in the proportion of 1,260 parts by the Duarte to 225 parts by the Beardslee company, the latter released to the former one-third of its one-half interest, so that two-thirds of the water right and works are now owned by the Duarte Mutual and one-third by the Beardslee company. Originally the two companies claimed one-third of the total flow of San Gabriel River. In the compromise agreement of 1889, by which all claims to the river water were adjusted, the Duarte companies were given title to three-tenths of the flow, surface and developed, when the total is equal to or less than 1,700 inches and $\frac{180}{720}$ of all excess over 1,700 inches.

In 1898 the San Gabriel Power Company acquired by right of salvage one-tenth of the total canyon flow, less 200 miner's inches, and disposed of this interest to the Covina Irrigating Company. Since this right was acquired, the total flow minus the above-mentioned proportion of salvage water has been divided as stipulated in the compromise agreement. As the flow of the San Gabriel fluctuates with the seasons and the rainfall, the supply of gravity water available for the use of the Duarte and Beardslee irrigators varies greatly in volume. During the irrigating seasons following dry winters, their combined share of San Gabriel River water sometimes falls as low as 75 inches. The maximum received is about 600 inches.

The Duarte and Beardslee irrigators claim and utilize the water of Fish Creek when the flow from that source is of sufficient volume to reach their system. This occurs only during the rainy season. The waters of Fish Creek after the winter storms are clearer than those of the San Gabriel and are preferred and taken, for at that season the use is confined for the most part to domestic service.

JOINT WORKS.

The Duarte and Beardslee share of the San Gabriel water is taken out from the main associated water companies' canal at the San Gabriel Power Company's station a short distance below the mouth of the canyon. The water is conducted westward across the old east-side gravel wash to the main river channel through a 30-inch wood pipe, 1,000 feet in length, and a bowlder and cement lined ditch 1,500 feet long. The river crossing is effected by means of a steel siphon 24 inches in diameter, sunk deep below the bed of the river and cased heavily in cement and rock. From the river channel westward to the point of division between the two companies, the work consists of 2,700 feet of rock-paved and cemented ditch, 1,200 feet of brick-lined culvert, and 1,300 feet of 26-inch cement pipe. The entire conduit from the point of diversion at the San Gabriel power house to the division box, near the east end of the Duarte tract, is about 1¾ miles in length and cost $15,000.

DUARTE MUTUAL IRRIGATION AND CANAL COMPANY.

The Duarte Mutual Irrigation and Canal Company was incorporated in February, 1882, and capitalized at $12,590, divided into 1,259 shares, the par value being $10 per share. The capital stock has not been increased, but the market value of each share is now about $100. The stock is transferable and not appurtenant to the land, but practically all of it is held by landowners.

Water is delivered to stockholders only, and is divided on the principle of measurement of time in proportion to holdings of stock—that is, if the owner of 20 shares is entitled to a run of one head for twenty-four hours, the owner of 30 shares is entitled to a run of one head for thirty-six hours. The regular irrigating head used is 35 inches, but the period of rotation varies with the amount of water available. When the supply is low the division is made on half time, and an irrigator who would ordinarily be entitled to a run of twenty-four hours receives water for only twelve hours. There is no charge for the water as such, but the running expenses of the company, which include zanjero's and secretary's fees and maintenance charges, amount to about $1 per acre per year. Betterments and interest on indebtedness and payments on principal are met by separate assessments, which have been as high as $9 per acre annually.

In 1900–1901 this company bought an acre of ground in the eastern part of the district, sunk a well (No. 73, Pomona quadrangle), and installed a 60-horsepower steam engine and Wigmore pump, at a cost of $17,000. The capacity of this plant is stated to be about 60 inches, and the water delivered costs the irrigators 1⅓ cents per hour-inch. In 1904 another well was sunk above the first plant and adjoining the company's main pipe line. This well is 133 feet in depth, and a 4 by 6 foot tunnel has been driven horizontally from the bottom of the shaft for a distance of 125 feet into the gravels. The well is equipped with a 60-horsepower gas engine and a No. 6 centrifugal pump. The cost of the plant was $10,000. These two wells are used to supply accessory water during periods when the canyon flow is low.

The main distributing system of the Duarte Company, below the point of division between it and the Beardslee Company, consists of a 3,000,000-gallon reservoir which cost $5,000, and two main cement conduits, each about 2½ miles long. The upper conduit is 22 inches in diameter and the lower 16 inches. These lines, together with the distributing laterals, cost $15,000. About 1,000 acres are under irrigation.

BEARDSLEE WATER DITCH COMPANY.

The Beardslee Water Ditch Company was incorporated in September, 1881, with a capital stock of $2,250, divided into 225 shares. In 1884 this was increased to $20,000, divided into 630 shares. The market value is reported to be about $100 per share. This company, as has been stated, receives one-third of the west-side San Gabriel waters and one-third of the flow of Fish Creek, and in addition to maintaining its own canals and reservoirs, assumes one-third of the expense of maintaining and repairing that part of the west-side system, which it owns jointly with the Duarte Mutual Irrigation and Canal Company.

Below the point of division between the two west-side companies the water of the Beardslee Company is conducted through 3 miles of 12- and 14-inch cement pipe to a reservoir above the company's lands. This reservoir has a capacity of 2,000,000 gallons, and was constructed in 1898 at a cost of $7,500. Below the reservoir the company owns about 1¾ miles of distributing pipe. Other laterals have been laid by stockholders at their own expense, and the company water is distributed largely through these private lines.

The available water is divided into two heads, and each share is given a run of one head for fifteen minutes each week. The company has no zanjero, but each irrigator has a schedule giving the exact time when he may use the water, and when the proper time comes he himself turns it on.

The company has no accessory pumping plants, and its expenses are light, so that the annual cost of the water to the users is only about $1 per acre. The crops raised are diversified, and include citrus and deciduous fruits, alfalfa, and garden products.

MONROVIA WATER COMPANY.

The surface flow from Sawpit Canyon, which discharges into the San Gabriel Valley just north of Monrovia, was divided originally between the Bradbury and Santa Anita ranches. In 1886 the Monrovia Water Company was organized, and in 1887 it acquired the Santa Anita rights. Improvements were at once instituted in the canyon system, and on the basis of these improvements the company claimed and later obtained possession of four-fifths of all water flowing there.

The original conduit was a 20-inch cement line running into the canyon about half a mile from the reservoir at its mouth. Below the reservoir the water was distributed through 2 miles of 12-inch cement pipe laid along the Santa Anita-Azusa grant line. After its purchase of the Santa Anita rights the Monrovia Water Company expended $60,000 in constructing pipe lines in Sawpit and one of its tributary canyons. About 17,000 feet of 6-inch, 10-inch, and 12-inch iron and steel pipe were laid in the two canyons and connected with the original cement line.

Finding that the canyon water was not sufficient to supply the needs of the city, the company bought 5 acres of land in 1898 for $1,700 on the Chapman ranch, 3½ miles to the west. Three wells were sunk on this property, an 80-horsepower steam and air plant was installed, a reservoir built, and a 12-inch pressure main laid eastward 5 miles to connect with the city system. The total cost of these improvements was about $40,000.

Originally the city of Monrovia sold water rights with the city property, but water is now disposed of independently of property interests, though none is distributed outside the city limits.

An average of 120 miner's inches is now distributed during the irrigating season, about two-thirds of it being used to irrigate 900 acres of land. The remainder is utilized as a domestic supply for 550 to 600 families. The irrigating water is distributed in 25-inch heads, each acre receiving this amount for not more than four hours during each interval of four or five weeks. Two cents per hour-inch is charged for this water.

SANTA ANITA COMPANY.

The Santa Anita Water Company was incorporated July 9, 1886, with a capital stock of $300,000, divided into 3,000 shares. The company was organized for the purpose of supplying water to the

Santa Anita tract of 3,000 acres, and stock was issued on the basis of one share per acre.

Originally controlling and utilizing one-half of the flow of both Sawpit and Santa Anita canyons, about the year 1890 the company entered into a contract with the city of Monrovia, by the terms of which it turned over to the city the control and use of the waters of Sawpit Canyon. It was stipulated in return that the city should supply those lands of the Santa Anita rancho that lie north of the south boundary of the city and east of an irregular line which conforms closely with its western boundary. The Santa Anita Water Company retained the half interest in the water and works of Santa Anita Canyon and undertook the delivery of water to stockholders west of Monrovia.

The works in Santa Anita Canyon were built jointly by the company and E. J. Baldwin, who owns one-half interest in the canyon waters. They consist of a low dam about half a mile above the canyon mouth, a short tunnel, the necessary gates and wasteways, and 1,800 feet of 20-inch cement pipe, leading to a partitioner, where the waters are divided between the joint owners. Below the partitioner are something more than 6 miles of 4-inch to 12-inch pipe, which serve as main conduit and distribution system.

The Santa Anita Company's share of this canyon water, stated by officers of the company to average about 25 inches during the irrigating season, is not sufficient to supply the needs of the irrigators, and a supplementary supply is procured from a well and pumping plant (No. 254, Pasadena quadrangle) belonging to E. J. Baldwin.

Canyon water is appurtenant to the Santa Anita tract, and is distributed only to shareholders, of whom there were nineteen in 1906.

BALDWIN SYSTEMS.

E. J. Baldwin holds in private ownership one-half the waters of Santa Anita and Little Santa Anita canyons, all of the flow from the ciénagas and artesian wells in the vicinity of Santa Anita, a part of the waters which rise in the moist lands above the Paso de Bartolo, and a number of pumping plants on the Santa Anita rancho, which are utilized as needed. The diversion works in Santa Anita Canyon have been briefly described in connection with the account of the Santa Anita Water Company, joint owner of the water, diversion dam, and main pipe line. The ownership in the Little Santa Anita water is shared with the Sierra Madre Water Company, and the works at the point of diversion are also jointly owned. These joint works consist of a tunnel 230 feet long at the head of the system, about one-third mile above the canyon opening, and a 10-inch cement pipe about 4,000 feet long which leads to a division box where the waters are partitioned between the two interests. Below this partitioner a 6-inch concrete pipe about 2 miles in length conducts the Baldwin share of the water to the lands on which it is used. This share is reported to amount to 10 or 15 inches during irrigating seasons, which follow winters of good rainfall.

The springs and artesian wells are distributed along the upper side of the irregular ridge which extends from above Monrovia to Raymond Hill. This district has always been an area of moist lands, and has furnished irrigation water since the settlement of the country. On the Santa Anita rancho are about 12 artesian wells, and the moist-land waters are collected by means of open ditches and tile drains; the combined yield from these sources is given as about 30 inches during the irrigating season.

Pumping plants have been installed at wells Nos. 273, 480, and 481 (Pasadena quadrangle), and when these are in operation a very much larger amount of water is obtained, their combined capacity being reported by the owner at 250 miner's inches.

Just above the Paso de Bartolo and between Lexington Wash and San Gabriel River the rising waters which are characteristic of this section are collected in earthen ditches and conducted through these and some small wooden flumes to lands within the pass and on either side of Rio Hondo, where they are used for irrigation. The flow in these ditches sometimes exceeds 150 inches.

In the vicinity of Santa Anita about 1,200 or 1,400 acres are under irrigation by the Baldwin and Santa Anita systems. Citrus and deciduous fruits, grapes, and alfalfa are grown.

SIERRA MADRE WATER COMPANY.

The Sierra Madre Water Company was organized by N. C. Carter, owner of the Sierra Madre tract, in 1882. At first there were 1,100 shares, one share to each acre of land in the tract, and as the par value of each share was $10, the capitalization was $11,000. August 24, 1894, the capital stock was increased to 8,800 shares, with a par value of $10 each. The original water supply came solely from Little Santa Anita Canyon, one-half of the surface flow of which belonged to the Sierra Madre Company and one-half to the owner of the Santa Anita rancho. This supply proving unreliable during the summer season, a well (No. 258, Pasadena quadrangle) was installed in the eastern part of the tract in 1900 and connected with the company's distributing system. Two engines are installed at the well, a 25-horsepower Columbus to operate the lift pump, and a 30-horsepower to operate the force pump, which drives the water up the slope to the higher parts of the system. The cost of the well, pumping plant, and distributing pipes is estimated at $13,000. Meters are installed in the system, and the pumped water is charged for at the rate of 10 cents per 1,000 gallons.

PRECIPICE CANYON WATER COMPANY.

The Precipice Canyon Water Company was incorporated in 1887 by four individual owners of all of the water rights in Precipice or Eaton Canyon. The organization was effected on the basis of 12,500 shares, the par value of each share being $50. Each of the incorporators received a number of shares directly proportionate to his original rights in the canyon waters. Since the organization 2,500 shares have been sold in small lots to fifteen or twenty individuals, while the remaining 10,000 shares are held by four stockholders.

The company owns 3 or 4 miles of pipe line. Some of the stockholders own small reservoirs, but the company itself owns none.

The water is divided among the shareholders, each owner receiving an amount proportionate to his ownership of stock. This water, however, is not appurtenant to the land, and shareholders need not be owners of realty. An owner of stock may, therefore, grant his proportion of water to whomever he may choose. About 120 acres of citrus fruits are irrigated by the system, and perhaps 200 acres of grapes receive water during the winter and spring. The expense of maintaining the system is borne by assessments on stock. The average cost is said to be about 25 cents per share.

W. I. Allen, manager of the company, furnishes the following table of flow from the canyon for a part of 1904 and 1905:

Flow from Eaton Canyon, in miner's inches.

	1904.	1905.		1904.	1905.
April	98.36	150.00	September	5.05	....
May	68.44	155.00	October	7.00	....
June	27.58	150.00	November	10.05	....
July	13.13	112.00	December	14.07	....
August	6.35	[a] 60.00			

[a] Approximate.

LINCOLN AVENUE WATER COMPANY.

The Lincoln Avenue Water Company was incorporated March 26, 1896, and capitalized at $72,000, divided into 7,200 shares, whose par value is $10 each. The individual interests that had held the rights to which the company succeeded transferred these rights to the company and received stock in payment; 3,670 shares have been issued; and the market value in 1906 was given as $8 per share.

The company holds all the water rights of Millard Canyon above the falls except those of Saucer Canyon, a small tributary which joins the main canyon from the north. This right and that of Millard Canyon below the falls are owned by the Giddings family, the water being used on Mountain View Cemetery, about 1 mile south of the base of the mountains.

The 700 acres of the Lincoln avenue tract, the water rights in Millard Canyon, and other lands and water rights were acquired by the Pasadena Improvement Company in the middle eighties. An 8-inch steel main was laid from the point of diversion in the canyon out to the head of the tract, reservoirs were built, and distributing lines were laid. This company, however, was disincorporated in 1893, and the water rights and such lands as had not been sold were divided among the stockholders. In 1896, as already stated, the present company was formed, largely of interests formerly included in the Pasadena Improvement Company. There are 30 to 40 stockholders in the company, all of whom are owners of property in the Lincoln avenue tract of 700 acres. Water, however, is not appurtenant to the land, and provision is made in the by-laws for distributing water outside the tract if desired. It is estimated that there are about 150 acres under irrigation.

In 1902 the company sunk a well (No. 436, Pasadena quadrangle) and installed a steam pumping plant. This plant is in operation twelve hours daily during the irrigating season, and is reported to yield 25 miner's inches. The canyon flow is said to vary from 3 to 20 inches, and since it is lowest during the summer and fall, pumped water is the principal reliance for irrigation. Canyon water, which is used for domestic purposes and during the spring and early summer for irrigation, is distributed for 1 cent per 1,000 gallons or less, which is something less than half a cent per hour-inch. Pumped water costs 6 cents per 1,000 gallons, or about 3 cents per hour-inch.

The well and pumping plant cost about $10,000. In addition, the company owns about 1½ miles of 8-inch steel main and 5 or 6 miles of 2- to 6-inch iron distributing pipe.

SUNNY SLOPE WATER COMPANY.

The Sunny Slope Water Company was organized by the Sunny Slope Land and Water Company and incorporated January 7, 1895, with a capital stock of $140,000, divided into 1,400 shares. The entire capital stock was issued to the land company and land was sold thereafter with one share of water stock to each acre. The water is made appurtenant to the 1,400 acres of land within the Sunny Slope tract and can not be delivered by the company outside of this area. The company has the right to develop water on 100 acres of ciénaga land surrounding its pumping plant (No. 465, Pasadena quadrangle). This tract is a part of the long, narrow belt of moist lands which lie on the north side of the "dike" extending from Raymond Hill, northeastward toward Santa Anita Wash. In the Sunny Slope area about 40 wells have been bored at various times, but the majority of them were long ago abandoned. The first of these wells was put in during the decade between 1860 and 1870, but the maximum flow is reported to have been obtained about 1890, at the end of the wet decade which included the winters of 1884 and 1887, with their exceptional rainfall. The artesian flow at that time is given as 140 inches, but has steadily declined since. During the irrigating season, while pumping is under way, the flow is now an inconsiderable amount.

In 1903 the Sunny Slope Water Company installed a centrifugal pump operated by a 20-horsepower motor. The plant, whose cost is given at $3,000, has a capacity of 70 miner's inches. The distribution system, built before the organization of the present company, includes an earthen reservoir, about 60 by 150 by 10 feet, and 4 miles of 4-, 6-, and 8-inch steel mains.

About 250 acres of orange and lemon orchard are irrigated by the company, and water is applied once annually to about 500 acres of vineyard. Water is distributed in 25-inch heads by schedule in rotation periods of six weeks, and is charged for at the rate of 7½ cents per miner's inch for a twelve-hour run.

CHAPEA WATER COMPANY.

The Chapea Water Company was incorporated July 22, 1896, and capitalized at $28,000, divided into 400 shares whose par value is $70 each.

During the year of organization the company purchased from Mr. Chapman, owner of the Chapman ranch, 40 miner's inches of water, paying therefor $500 per inch. At that time the water was artesian, but with increased drafts on the basin and the installation of pumping plants on adjacent wells, those from which the Chapea Company is supplied ceased to flow and a pumping plant was installed over them. The 40 inches furnished in 1905 werepumped. The company has no reservoir, but owns 4 miles of 10-, 6-, and 4-inch riveted steel pipe, laid in 1896 at a cost of about $8,000.

Each irrigator receives in a continuous flow during the irrigating season a share of the water proportionate to his holdings of stock. The irrigation is accomplished on the basis of 1 miner's inch to 5 acres. Two hundred acres planted to oranges are under irrigation. The total cost to the irrigators, including the salary of $60 per year which the secretary, the only paid officer of the company, receives, is $1,200.

GARVEY WATER COMPANY.

The Garvey Water Company was organized in 1892, and capitalized at $50,000, divided into 1,000 shares, with a par value of $50 each. The company owns a well and pumping plant (No. 58, Pasadena quadrangle) in the old artesian belt 1 mile northwest of North San Gabriel, and the water developed there is carried through about 6 miles of 8-inch steel main to a reservoir in the hills south of San Gabriel Valley, overlooking the Garvey tract, upon which the water is used.

This reservoir and main were constructed in 1892 at a cost, as given by the company's officers, of $31,000. The well is reported to have yielded 70 inches of gravity water at the time of purchase, but during the three years from 1903 to 1905 it was necessary to pump during the irrigating season, although the gravity flow at the point where the well is tapped, 20 feet below the surface, was sufficient for a domestic supply for the tract. A centrifugal pump and a 16-horsepower electric motor, supplied with power from Pasadena, are used when pumping is necessary.

About 200 acres are irrigated, the water costing the users at the rate of $2.50 for a ten-hour run of 30 miner's inches, or five-sixths of a cent per hour-inch. Each acre is given a two and one-half hour run of 30 inches monthly.

ALHAMBRA ADDITION WATER COMPANY.

The Alhambra Addition Water Company was incorporated in December, 1883, with a capital stock of $250,000, divided into 2,500 shares, of a par value of $100 each. The rights to the surface flow of El Molino Canyon, which cuts through the Raymond "dike" about 1 mile east of Raymond Hill, were purchased from the owner, and 50 inches of water were diverted. Up to 1905 ten wells had been sunk in the canyon, several of which are pumped by the 30-horsepower steam plant and air compressor that have been installed. The capacity of the plant is given by the company as 150 inches. A number of the wells are not connected with the pumping plant, but have been tapped several feet below the surface. The flow from these and from the canyon aggregated about 20 inches in the spring of 1905.

The company owns about 20 miles of distributing pipe from 4 to 16 inches in diameter, laid between 1876 and 1905, from the canyon to Alhambra. It also has constructed one 4,000,000-gallon reservoir, and three with a combined capacity of 2,000,000 gallons. It owns 27 acres of land—17 acres in El Molino Canyon and the balance in reservoir sites.

One thousand acres of land in Alhambra and vicinity are irrigated at an annual cost to the irrigators of $1 per acre. The water is delivered in 25-inch heads, at the request of irrigators.

EUCLID AVENUE WATER COMPANY.

The Euclid Avenue Water Company was incorporated December 24, 1900, with a capital stock of $25,000, divided into 2,500 shares, whose par value is $10 each. Its organizers are the owners of 165 acres constituting the Los Robles tract, and of a right to 17½ inches of water in Los Robles Canyon, a short distance east of the Raymond

Hotel. So far 1,325 shares have been issued; these are held exclusively by owners of realty in the Los Robles tract.

The first development work in the canyon was a tunnel which furnished a gravity flow. This flow ceased in 1898. In 1901, after the organization of the present company, a small tract of land was bought in Los Robles Canyon for $250, a well (No. 53, Pasadena quadrangle) was sunk, and a small pumping plant was installed. At the same time another small tract half a mile farther up the canyon was purchased. This tract is held in reserve. The well in use is equipped with a centrifugal pump, run by a 15-horsepower motor. It is reported that 26 inches of water are developed.

The company owns 1½ miles of steel distributing pipe and a reservoir of 1,000,000 gallons capacity. The pipe lines were laid and the reservoir constructed in 1891.

The 165 acres of the original tract are irrigated at a cost of $15 per acre per year, but no water is sold outside this tract. The water is distributed in heads of 40 weir inches, "Pasadena module" (equivalent to about 18 miner's inches), at intervals of approximately six weeks.

MARENGO WATER COMPANY.

The Marengo Water Company was organized December 27, 1884, on the basis of a capitalization of $250,000, divided into 5,000 shares, with a par value of $50 each. An area of 1,250 acres, comprising what was originally known as the Bacon ranch, but later was divided into the Raymond Improvement Company tract and the Marengo tract, is entitled to water, four shares of stock having been allotted to each of the original 1,250 acres.

The first source of water for this acreage was a series of springs which represented overflow from the Pasadena Basin across the Raymond Hill dike, but as these springs dried away the water supply was maintained by developments consisting of wells and tunnels along San Pasqual Wash to the north and west of Raymond Hill. The first tunnel was driven under the hills west of the Raymond Hotel in 1883, and for a time furnished a supply of about 20 miner's inches, but this flow dwindled and the tunnel is not now used. A later tunnel driven east of Raymond Hill into San Pasqual Wash furnishes a constant flow, which is given as 45 inches during the winter months and 30 inches during the summer months. In addition to this tunnel development the company has in use two 12-inch wells, located at the upper end of San Pasqual Wash, in the south end of the Pasadena Basin. An Ames pump driven by a gasoline engine and a Wood pump driven by electrical power constitute the equipment of these wells, which are reported to yield about 40 inches each.

The distribution system includes a covered and cement-lined reservoir 450 by 100 by 7½ feet, with a capacity of 2,500,000 gallons. There are a number of miles of pipe line from 2 to 10 inches in diameter and 220 meters representing domestic users. Only about 160 acres of the original tract are now under cultivation as agricultural lands, and these are planted to orange groves almost exclusively. The rate charged for water used in irrigation is $2 per day of ten hours for a head of 25 weir inches. For water used for domestic purposes $1.25 is charged for the first 1,300 cubic feet and 6 cents per 100 cubic feet for all in excess of this amount.

MONTEBELLO LAND AND WATER COMPANY.

The Montebello Land and Water Company was incorporated February 10, 1900, and capitalized at $125,000, divided into 1,250 shares, with a par value of $100 each. The company was organized for the purpose of supplying the Montebello tract of 1,250 acres, lying 3 or 4 miles southwest of the Paso de Bartolo, with water. One share of stock is issued with each acre of land sold. This share entitles the holder to a twelve-hour run of 7½ inches monthly, a rate of about 1 miner's inch to 8 acres. Extra water, which will be furnished if available after all regular orders are filled, is charged for at the rate of $8 for a twelve-hour run of 100 inches, or two-thirds of a cent per hour-inch.

The pumping station (No. 279, Pasadena quadrangle) which furnishes the water is situated on the mesa about one-fourth mile east of Rio Hondo and one-half mile north of the Los Angeles-Whittier road. It consists of six wells operated by two plants, a cross compound Corliss engine and centrifugal pump, and a Worthington engine and pump. These plants develop 110 horsepower and the company gives their capacity as 300 inches, with an output of 225 inches during the irrigating season. The tract of 1,250 acres lying west of the station has been piped with 4-inch and 6-inch steel distributing lines, of which 12 miles have been laid. Two reservoirs have been built whose combined storage capacity is stated to be 6,500,000 gallons. The total investment is summarized by the company's officers as follows: Wells and pumping plants, $35,000; pipe lines, $20,000; reservoirs, $3,000; total, $58,000.

Six hundred acres were under irrigation during the season of 1905. Berries, vegetables, citrus fruits, and walnuts are grown.

NORTH PASADENA LAND AND WATER COMPANY.

The North Pasadena Land and Water Company was incorporated in 1885 with a capital stock of $90,000, divided into 1,800 shares, whose par value is $50 per share. In 1880 J. H. Painter and B. F. Ball had acquired 1,800 acres of land on the east bank of Arroyo

Seco, beginning perhaps 1 mile below the mouth of the canyon and extending thence eastward and southward. At the same time rights to all water flowing in the main canyon above its lower tributary, Millard Canyon, were secured. In 1887 a 10-inch by 12-inch cement pipe something more than 2 miles in length was laid to the tract. This property was all turned over to the North Pasadena Land and Water Company after its incorporation, the former owners of the property receiving stock in payment. Land was then sold, with one share of water stock to each acre, and the control of the company passed into the hands of the landowners.

The old pipe line from the canyon to the company lands was replaced in 1893 by a vitrified-clay and steel main, ranging from 13 to 18 inches in diameter. The water from springs and small tunnels in the upper part of the canyon and its tributaries is collected and carried to the head of the main-canyon conduit through several miles of small iron pipe.

The total gravity flow from the canyon attains considerable volume during the winter and is usually sufficient for the needs of the tract during the spring and early summer, but has to be augmented by pumped water during the summer and fall. The average gravity flow during the summer months, July to November, 1904, following a dry winter, was 4.3 miner's inches. The following series of measurements, taken during the wet winter and spring of 1905, represent contrasting conditions:

Gravity flow from Arroyo Seco canyon, 1905.

	Miner's inches.		Miner's inches.
January 12	55	March 25	2,620
January 19	58	March 31	1,356
January 25	99	April 7	725.5
February 18	2,700	April 15	877.5

About 1895 this company, pursuing a policy forced on the majority of the water companies owning gravity systems in the southern part of the State at that time, prepared to develop underground waters, with which to augment the surface supply. Water-bearing lands were bought, and two wells were sunk (Nos. 435 and 437, Pasadena quadrangle) and equipped with pumping machinery. One of these (No. 435) is about half a mile north and half a mile east of Devils Gate, and is 160 feet deep. A 35-horsepower engine and deep-well plunger pump are installed. The other well (No. 437) is about three-fourths of a mile south of Devils Gate and but a few hundred feet east of the Arroyo Seco canyon. Originally 96 feet deep, it was sunk to 135 feet in 1904 in consequence of the lowering of the water plane. The well is evidently north of the bed-rock spur which extends from the banks of the arroyo toward Monk Hill and dams back the ground waters above it. The bottom of the shaft did not reach bed rock, but probably closely approached it. The output of these two wells from July to November, 1904, is reported to have averaged 87 inches. The greater proportion of the water is furnished by the lower well, because as its lift is less it is operated more constantly.

The company reports that the cost of its pumped water during 1904 amounted to $2.78 per 1,000 gallons, or $48 per miner's inch per year. Irrigation water is supplied at 3 to 5 cents per hour-inch (miner's, not "surface" inch), the charge varying with the proportion of pumped and gravity water. The water is distributed in rotation in heads of 20 "surface" inches (about 9 miner's inches) at intervals of thirty days. The output is apportioned in proportion to holdings of stock. An area of 173 acres, belonging to 25 irrigators, is supplied by the company.

In addition to this irrigating water, domestic water was supplied in 1905 to 972 taps, at the following rates: One thousand cubic feet or less, $1.50; first additional 1,000 cubic feet, $1; each additional 100 cubic feet, 6 cents. The daily consumption of domestic water in 1905 was 1,065,000 gallons, and on the basis of four users to each tap, 3,888 people were served and the rate of consumption was 275 gallons per capita daily.

The company's pipe system includes the main-canyon conduit, 5,000 feet of 16- and 18-inch vitrified-clay pipe, 6,450 feet of 13-inch iron pipe, and about 26.2 miles of steel pipe from 1 to 14 inches in diameter in the distributing system. Two reservoirs, concrete and asphalt lined and roofed, also form a part of the system.

PASADENA LAKE VINEYARD LAND AND WATER COMPANY.

ORGANIZATION AND TERRITORY.

The Pasadena Lake Vineyard Land and Water Company was incorporated in January, 1884, with a capital stock of $250,000, divided into 5,000 shares, the par value being $50 per share. This company, spoken of generally as the "east side company," delivers irrigating and domestic water to Pasadena east of Fair Oaks avenue, and to lands outside of the city limits, eastward from Pasadena toward Lamanda. The greater part of the territory supplied lies within the boundaries of the original 2,500-acre Lake Vineyard tract, of the San Pasqual rancho. Consumers located within the limits of this tract can purchase water from the company without owning stock, but outside residents, in order to obtain water, either for domestic use or irrigation, must become shareholders. The area under irrigation in the Lake Vineyard tract is said by Wm. Ham. Hall to have reached 2,000 acres in 1884, but with the expansion of the city of Pasadena a large part of the orchards and vineyards which formerly covered this area have been divided into town lots, and streets have been cut through to afford them frontage. As a result the area of irrigated lands has steadily diminished until at the present time it is estimated that the company supplies, within and without the original tract, a total of not more than 200 acres with irrigating water. By far the greater part of the revenues of the company is derived from the sale of domestic water within the city limits of Pasadena.

WATER SUPPLY.

The water supply of the Pasadena Lake Vineyard Land and Water Company is derived from wells and tunnels near Devils Gate, on the east side of Arroyo Seco, and from wells on the mesa near the reservoir at the head of the Lake Vineyard tract. The works and water rights at Devils Gate are owned jointly by the Pasadena Lake Vineyard Company and the Pasadena Land and Water Company in the proportion of seven-tenths to the former and three-tenths to the latter company. The Copelin and Banbury wells and pumping plants (No. 432, Pasadena quadrangle) are independent properties of the Pasadena Lake Vineyard Company.

HISTORY OF WATER RIGHTS.

In 1874 the Lake Vineyard Land and Water Association was incorporated and acquired 2,500 acres of the San Pasqual rancho, adjoining the San Gabriel Orange Grove Association's tract on the east, with a part interest in the springs immediately above and below Devils Gate. It was the object of the company to divide the tract into small lots, sell these, and grant to each purchaser an interest in the water, proportional to the amount of land purchased. The company's share of water was made appurtenant to the 2,500-acre tract, and a concrete-lined ditch 13,000 feet long was constructed to deliver water from the springs to a reservoir on the mesa at the head of the company's lands. Distributing pipe was laid from the reservoir, and lands under the system were sold, one share or a five-hundredth interest in the water being conveyed with each 5 acres of land, with the right to the use of the company's canal and pipe lines for delivery. In 1883, after having disposed of 1,500 acres of the 2,500-acre tract, the company sold an undivided tenth interest in its waters, and an undivided three-tenths interest in its water-bearing lands to the San Gabriel Orange Grove Association, and the remaining interests not disposed of to a syndicate of twelve residents of Pasadena. The original interests having thus become scattered with no strong central organization in control, no effective administration was possible, the canals and pipe lines were neglected, and the entire system deteriorated. Accordingly, the Pasadena Lake Vineyard Land and Water Company was organized in 1884 by a large majority of the purchasers of land and water rights from the old association for the purpose of repairing the system and acquiring and developing a greater quantity of water. These granted to the new corporation their interests, and received therefor shares of the corporation stock, 10 shares being issued for each of the old 5-acre water rights. A few of the holders of the water rights purchased from the old association declined to join the new organization and did not convey their interests. The new company repaired the system and developed the springs, greatly increasing their flow. To enable this work to be carried out, assessments on stock amounting to $8.37 per share were levied. A definite water rate to stockholders was also fixed, the figure being made high enough to cover the cost of operation and of repairs. In 1885 suit was brought by the Lake Vineyard Land and Water Company to determine the ownership of water rights as between the old Lake Vineyard Association and the Orange Grove Association. This suit was subsequently compromised and the Pasadena Land and Water Company, which had succeeded to the rights of the Orange Grove Association, was given title to three-tenths of all the water of the Devils Gate springs, the Lake Vineyard Company retaining title to seven-tenths.

After the organization of the Lake Vineyard Land and Water Company, some of the holders of the original water rights who had remained outside of the corporation attempted to establish a pro rata interest in the water developed by the company by paying their share of the expense of operation. George W. Beck, one of those who had succeeded to $\frac{1}{1250}$ of the original water rights, as appertaining to 2 acres, refused to pay the rate charged him for water by the company and applied for a permanent injunction to restrain the directors from discontinuing service in supplying him with his share of water. A decision was rendered by the State supreme court in December, 1889, defeating the plaintiff. In 1894 the parent organization, the Lake Vineyard Land and Water Association, was disincorporated.

DEVILS GATE JOINT WORK.

In 1887 the Pasadena Land and Water Company and the Pasadena Lake Vineyard Company joined in laying a 22-inch lapped and riveted steel conduit, to replace the old open ditch, from the Devils Gate springs to a point of division on the mesa at the main reservoir. About 1891 the two companies, finding the flow from the springs inadequate for their needs, began the construction of works to develop and bring to the surface the waters of the underflow of Arroyo Seco and the east-side mesa. About 1891, 2,008 feet of tunnel were constructed through the rocky point on the east side of Devils Gate into the east-side mesa and under the gravel beds of the arroyo. Beginning at the lower end of the gorge and passing northward into the point of rocks for about 100 feet, the tunnel was divided into two branches, the right-hand branch taking a northeast course into the mesa a distance of 600 feet, and the left-hand branch a northwest course for a few hundred feet to a second fork. From this second dividing point another branch was continued westward and under the stream bed at the upper end of Devils Gate, while the main work was extended nearly due north about 1,000 feet under the bed of the arroyo close to the east-side mesa. In 1895 the main tunnel was extended from its northern extremity eastward into the mesa a distance of 2,529 feet. In 1902 two wells were sunk (Nos. 434 and 434a, Pasadena quadrangle) and a further extension of the tunnel of 337 feet was made to these wells. The tunnel tapped the wells at a depth of 175 feet from the surface. These wells flow and are pumped by compressed air into the tunnel. They have a depth of 375 and 575 feet, respectively. A third well has been sunk recently and is being connected with the tunnel.

In 1897 a submerged dam was built across the narrows at the upper end of Devils Gate, immediately below the west branch of the tunnel (Pl. II, *B*, p. 52). The underflow of the arroyo is held by this dam, while the tunnel taps the gravels and leads the water into the pipe system below. At the extremity of this branch on the west side of the stream channel an opening is provided for the admission of the storm waters. In 1897 a solid masonry dam was laid in the bed rock a short distance within the mouth of the tunnel, and a valve was constructed by which the tunnel can be sealed entirely or the flow partially cut off at will. As a result of closing the tunnel in winter the water plane in the wells above rises about 20 feet. That the general water plane in the area surrounding the wells is raised is evident also from the fact that an increased flow comes from the wells for weeks after the opening of the tunnel.

In 1903 a 100-horsepower compressed-air plant was installed at the mouth of the tunnel below Devils Gate. Compressed air is piped from this plant to the wells described above, and by its use water is raised to the tunnel level, whence it flows by gravity past the plant into the main conduit below. The gravity flow from the tunnels and wells varies with the seasons. The tunnels are partially sealed during the winter months, so that no measurements of the total flow are available. During the summer the pumping plant is in operation for a variable period, whose length depends on the previous winter's rainfall and the amount of gravity water available. During the summer of 1906 it was not found necessary to start the pumps at all, because of the copious rainfall of the two preceding seasons. Engineers who have studied the local situation thoroughly express the belief that if pumping operations were suspended for a considerable period of time the gravity flow would reach 100 miner's inches.

Records of measurements taken in 1904 of gravity and pumped water discharged from the tunnel and tunnel wells show on August 1, after the pumping plant had been shut down three hours, a gravity flow of 55.05 miner's inches; on the same day, after the plant had been shut down seven hours, a flow of 53.25 miner's inches; and on August 4, after a nine-hour shut down, a flow of 53.25 miner's inches. The officers of the company call attention to the facts that during the seven years preceding 1904 the rainfall had been low, and that periods of three to nine hours after closing the pumps may not be sufficient to allow the maximum flow to be reached.

OTHER WORKS IN ARROYO SECO.

In addition to the main work, three minor tunnels have been constructed and a pumping plant installed in the arroyo along the pipe line within half a mile of the mouth of the main tunnel. About 1889 a shaft (well No. 433, Pasadena quadrangle) was sunk close to the east bank of the arroyo, a few hundred feet below the mouth of the main tunnel, and a short tunnel was driven westward under the bed of the arroyo a distance of 288 feet. A pumping plant was placed over the shaft and equipped with a 12-horsepower gas engine and No. 4 centrifugal pump. This plant has a capacity of 25 inches for twelve hours. In 1894 a tunnel 575 feet long was driven eastward into the mesa at Wilson's Spring and another 665 feet in length at Richardson Springs. These works are located along the bank of the arroyo about half a mile below the main plant. August 1, 1904, the Wilson tunnel was flowing 3.79 miner's inches, and August 4, 1904, the Richardson tunnel was flowing 8.35 miner's inches.

INDEPENDENT PROPERTY.

Besides the Arroyo Seco properties, which are held in joint ownership with the Pasadena Land and Water Company, the Lake Vineyard Company has two independent wells and pumping plants (No. 432, Pasadena quadrangle). These are known as the Copelin and Banbury wells and are located on the mesa a short distance above the main reservoir. The Banbury well is not in active use at the present time, but in April, 1905, a 200-horsepower Corliss engine and a centrifugal pump were installed on the Copelin well, raising the normal output of the plant to nearly 200 inches.

DISTRIBUTION.

Water for irrigating purposes is delivered on orders filed at the office of the company and filled in succession. Water is distributed in heads varying in volume from 5 to 25 weir inches ("Pasadena module") and charged for at the rate of 1 cent per hour-inch. It is estimated that the company supplies about 200 acres with irrigating water.

Domestic water is metered and a charge of $1 is made for 600 cubic feet and 5 cents per hundred for each additional 100 feet. The company has 1,958 meters in use.

VALUE OF PROPERTIES.

October 15, 1904, T. D. Allin, city engineer, and Lippincott & Parker, consulting engineers, submitted a report to the city of Pasadena on the properties of the Pasadena Land and Water Company and the Pasadena Lake Vineyard Land and Water Company. In this report the works of each company are described in detail and a careful estimate is made of their present value. The following valuation is summarized from this report:

Summary of values of the property of the Pasadena Lake Vineyard Land and Water Company (east-side system) exclusive of real estate, water, and water rights.

	Cost, new.	Depreciation.	Present value.
Pipe system purchased prior to January 1, 1889	$22,897.24	$9,625.63	$13,271.61
Pipe system purchased since January 1, 1889	103,220.63	29,502.20	73,718.43
Meters purchased prior to June, 1900	15,384.30	3,846.08	11,538.22
Meters purchased since June, 1900	8,007.00	556.84	7,450.16
Air valves	78.00	24.36	53.64
Gate valves	3,536.48	636.57	2,899.91
Specials	1,527.04	546.71	980.33
Clamps	431.75	154.58	277.17
Bands	124.97	44.71	80.26
Banbury well	3,175.70	1,561.26	1,614.44
Copelin well	13,632.54	3,553.60	10,078.94
Reservoir No. 1, less three-tenths of division box	19,245.36	806.99	18,438.37
Reservoir No. 2	49,083.60	1,874.97	47,208.63
Dry tunnel, seven-tenths	2,377.44		2,377.44
Wagon road and fence, seven-tenths	453.68	23.10	430.58
Office furniture	500.00		500.00
Total value of construction work, including Banbury and Copelin wells and not including other water-development work	243,675.73	52,757.60	190,918.13
Add 20 per cent for engineering, administration, contractor's profits, etc			38,183.63
Value of the going business			13,500.00
			242,601.76

This is the estimated value of the property exclusive of the Devils Gate developments, property outside of the city of Pasadena, and real estate.

The engineers, in endeavoring to arrive at the value of the Devils Gate waters, concluded that the works there would deliver to the systems 100 inches of gravity water or 200 inches of pumped water, and under the conditions which existed in Pasadena at that time the gravity waters were valued at $2,000 and the pumped waters at $1,000 per miner's inch; so that whether the waters procured by the Devils Gate developments are regarded as the lesser amount at the higher valuation or the greater amount at the lower valuation is immaterial. The total value by either method of reckoning is $200,000. In this calculation the value of the works by which the water is developed is included in the estimate. Since seven-tenths of the Devils Gate developments belong to the Pasadena Lake Vineyard Land and Water Company, its interest in the total amounts to $140,000. The city engineer, T. D. Allin, has estimated the value of that portion of the company's plant outside of the city of Pasadena at $18,531.95, and a special commission appraised the real estate at $34,816.97. The total valuation of the east-side company's property, therefore, may be summarized as follows:

Value of property of Pasadena Lake Vineyard Land and Water Company.

Plant in Pasadena (exclusive of Devils Gate interests) pipe system, reservoirs, going business, etc	$242,601.76
Seven-tenths interest in Devils Gate developments	140,000.00
Real estate	34,816.97
Portion of plant outside of Pasadena	18,531.95
	435,950.68

PASADENA LAND AND WATER COMPANY.

ORGANIZATION AND TERRITORY.

The Pasadena Land and Water Company was incorporated in March, 1882, with a capital stock of $50,000, divided into 200 shares with a par value of $250 each. In December, 1885, the capital stock was increased to $75,000 and the number of shares to 3,000, the par value of each share being reduced to $25.

This company, usually spoken of as the "west-side company," to distinguish it from the Pasadena Lake Vineyard Land and Water Company, known as the "east-side company," serves an area of about 1,500 acres, lying in a strip less than a mile wide and about 4 miles long on the east bank of Arroyo Seco. Two-thirds of this area is at present in the city of Pasadena, and one-third in the separate municipality of South Pasadena. Only about 100 of the original 1,500 acres are now under irrigation, the remainder being occupied by homes and users of domestic water.

WATER SUPPLY.

The water supply of the west-side company is derived from the Devils Gate developments, owned and controlled jointly by the east-side and west-side companies, title to three-tenths of the works and of the water developed being in the latter, from the Sheep Corral Springs developments, which belong exclusively to the west-side company, and from the Bradford street well, the Culver well, and the Glenarm street well.

The capacity of the Devils Gate developments is estimated at 200 inches of pumped water, and the west-side interest of three-tenths of this amounts to 60 inches. The Sheep Corral developments have yielded 90 inches or more in the past, but, as this is regarded in excess of the permanent supply, the capacity of the works is placed at 50 inches. The Bradford street well yields 8 inches during the summer months, the Culver well yields about the equivalent of 10 inches constant flow, and the capacity of the Glenarm street battery of wells with present water levels is given as 90 inches. The total available permanent supply for the west-side company with its present installation, therefore, amounts to about 218 miner's inches.

HISTORY OF WATER RIGHTS.

In 1873 an association was formed at Indianapolis, Ind., under the title of the Indiana Colony, for the purpose of settlement in southern California. The association's representatives acquired 4,000 acres of land in two tracts, one of 1,500 acres along Arroyo Seco, and the other of 2,500 acres in the Altadena and Mesa de Las Flores neighborhoods. Title to all the waters at Sheep Corral Springs and to an interest in the waters about the Devils Gate was purchased with these lands. Only about twelve of the original Indiana colonists emigrated to California, but the uncalled-for shares were taken in Los Angeles and the general plan was carried through. The subscribers, of whom there were about thirty, then organized and incorporated the San Gabriel Orange Grove Association, with 100 shares, each share entitling the holder to a 15-acre subdivision of the lower 1,500-acre tract. The water rights and the 2,500-acre tract were not subdivided, but were held for the benefit of the association as a whole, and afterwards the latter tract was sold and the proceeds invested in improvements in the water system, etc.

A series of disputes between the east-side and west-side parties at interest as to the ownership of the waters in the springs about Devils Gate began in the seventies and was not finally settled until a compromise was effected in 1885. The first of these suits was decided in 1879 adversely to the interests of the Orange Grove Association. In July, 1883, the association bought from the east-side organization for $10,000 an undivided one-tenth interest in its waters and an undivided three-tenths interest in its unsold water-bearing lands and main conduit. By the terms of the compromise of 1885, these purchased interests were accepted as equivalent to a three-tenths interest in all the waters of all the upper springs, title to the remaining seven-tenths remaining in the east-side company. This adjustment has served as the basis for the distribution of all costs of improvements and maintenance, and for the division of all Devils Gate waters since it was effected. The Sheep Corral waters and water rights have never been in dispute, but have been acknowledged as the property of the west-side company since the predecessors in interest of the Indiana Colony first purchased the San Pasqual rancho in 1858.

The Bradford street well, situated on a lower bench just west of Arroyo Seco, was dug and a pumping plant installed over it in 1903; the Culver well, on the east side of the arroyo, was purchased from F. J. Culver in 1904 for $8,000, and the Glenarm street wells, one-fourth mile northeast of the Raymond Hotel, were bored and equipped in the summer of 1904.

DEVILS GATE JOINT WORKS.

A brief account of these works, constructed and owned jointly by the Pasadena Land and Water Company and the Pasadena Lake Vineyard Land and Water Company, is given on pages 126–128.

INDEPENDENT PROPERTY.

The oldest of the water sources owned exclusively by the Pasadena Land and Water Company is the Sheep Corral Springs and development works. Before the sinking of wells and driving of tunnels in their immediate vicinity and the completion of more distant developments which have nevertheless affected their supply, these springs yielded from 50 to 130 miner's inches during the dry months of summer, and their average flow was given by Wm. Ham. Hall[a] as 90 miner's inches.

As the demand for water on the Pasadena mesa increased, work was undertaken at the springs, with the purpose of increasing the supply available from them. In 1890 a tunnel was begun just above the gorge at Sheep Corral Springs, at a depth of 29 feet, and during the three succeeding years it was extended northward until it reached a length of 1,345 feet, its construction having cost $14,500. At the same time (1890) a small gasoline engine was installed for the purpose of lifting the water developed in the tunnel into a receiving tank, whence it was pumped with other waters from the springs to a reservoir on the edge of the mesa 100 feet above the arroyo level. The plants for this greater lift were installed in 1882 and in 1892, and consist of two Wellington compound duplex pumps, each with a capacity of 100 miner's inches. In 1895, in order to recover whatever underflow might be escaping through the gravels of the gorge below the springs, a submerged dam was constructed across this gorge and extended from bed rock to 4 feet above the original surface of the gravels in the arroyo. The dam, which is of concrete-masonry construction, has a maximum depth of 28 feet, and a width of 4 feet and contains 336 cubic yards of material. Its cost was $5,200. Finally, in 1904 a well was sunk in the tunnel and water is now pumped from 40 feet below its floor.

---

[a] Irrigation in Southern California, 1888, p. 406.

The Bradford street well was dug in 1903. It is located in Pasadena, just west of Arroyo Seco and something more than 1 mile south of Sheep Corral Springs. From the bottom of the well, which is 70 feet deep, a drift extends eastward for 170 feet. The well is operated by electric power, and the water, about 8 miner's inches, is pumped directly into the South Pasadena main, which runs near by.

The Culver well, on the east side of the arroyo, about 600 feet north of the Bradford street well, was sunk in 1899 and 1900 by F. J. Culver, and was purchased by the Pasadena Land and Water Company in 1904 for $8,000. The well is 54 feet deep, and a tunnel extends northeastward 122 feet from its bottom. Water from this well is pumped into the South Pasadena main directly by electric power. The yield is approximately 40 inches for the six hours per day during which it is pumped. Neither the Bradford street nor the Culver well is used except during the dry periods of mid and late summer.

The latest addition to the Pasadena Land and Water Company plants is the Glenarm street group of three 12-inch wells, bored and equipped with a pumping plant in 1904. These wells are located about one-fourth mile northeast of the Raymond Hotel. They vary in depth from 215 to 256 feet, and their total cost was $1,840. An air lift has been installed to pump the water from the wells, and a centrifugal pump then raises it over the Orange Grove avenue ridge into the South Pasadena main. From this main the water will flow by gravity to the Sheep Corral plant, and may then be pumped into the Pasadena system. The cost of this pumping plant is given as $7,023, and its capacity as 90 inches. The wells easily yield this amount, and inasmuch as their situation is most favorable, both as to permanence of supply and accessibility of water, it is probable that they will continue to furnish the full amount for a long period.

DISTRIBUTION.

Although the San Gabriel Orange Grove Association, to whose rights and property the Pasadena Land and Water Company has succeeded, was essentially an irrigation company, the present corporation, through the growth of the cities of Pasadena and South Pasadena, has become in reality a municipal water company. Only about 100 of the 1,500 acres in the original tract are now under irrigation.

Within the city limits of Pasadena practically all services are under meter, the company having about 1,200 instruments in use. The minimum charge for water where meters are installed is $1.25 per month. This sum entitles the user to 800 cubic feet. For all water in excess of that amount a charge of 6 cents per 100 cubic feet is made. In South Pasadena and at those few points in Pasadena where meters are not installed, flat rates of 50 cents to $2 per month are charged. The irrigating rate is 1¼ cents per hour per "surface inch," probably equivalent to a little more than 2¾ cents per hour per California miner's inch.

VALUE OF PROPERTIES.

The board of engineers, Messrs. Allin, Lippincott, and Parker, engaged in 1904 to determine the value of the property of the companies supplying Pasadena with water, summarized the value of the system, exclusive of the interest in the Devils Gate works, the Sheep Corral developments and rights, the South Pasadena portion of the system, and the real-estate holdings, as follows:

Summary of values of the property of the Pasadena Land and Water Company (west-side system) exclusive of real estate, water, and water rights.

	Cost new.	Depreciation.	Present value.
Pipe system	$78,234.52	$25,500.46	$52,734.06
Gate valves	1,655.18	297.93	1,357.25
Specials	848.12	276.49	571.63
Meters laid prior to June, 1900	8,795.10	2,506.59	6,288.51
Meters laid since June, 1900	6,557.50	565.11	5,992.39
Orange Grove avenue reservoir	26,929.67	5,088.65	21,841.02
Bradford street pumping plant	4,553.24	339.54	4,213.70
Glenarm street wells	1,840.20	....	1,840.20
Glenarm street pumping plant	7,023.42	....	7,023.42
Sheep Corral main pumping plant	8,480.81	3,869.33	4,611.48
Division box, three-tenths	40.50	....	40.50
Dry tunnel, three-tenths	1,018.91	....	1,018.91
Wagon road and fence, Devils Gate, three-tenths	194.43	9.89	184.54
Tool house and office furniture	500.00	....	500.00
Total value of construction work, including Glenarm and Bradford street wells, and not including other development work	146,671.60	38,453.99	108,217.61
Add 20 per cent for engineering, administration, contractor's profits, etc	....	....	21,643.52
Value of the going business	....	....	10,000.00
	....	....	139,861.13

The Devils Gate developments (see pp. 126–128 for details) are valued at $200,000, three-tenths of which, or $60,000, belong to the west-side system. The water supply from Sheep Corral Springs was valued at $500 per miner's inch, and the permanent supply there estimated at 50 miner's inches, or a total valuation of $25,000. T. D. Allin, city engineer of Pasadena, estimated that portion of the company's plant outside of the city to be worth $15,295.73, and the real estate commission estimated the value of the real estate holdings of the corporation to be $49,603.28.

The final valuation of the west-side company's property may therefore be summarized thus:

Value of property of Pasadena Land and Water Company.

Plant in Pasadena (exclusive of Devils Gate and Sheep Corral developments)	$139, 861. 13
Three-tenths interest in Devils Gate developments	60, 000. 00
Sheep Corral developments and supply	25, 000. 00
Real estate	49, 603. 28
Portion of plant outside of Pasadena	15, 295. 73
	289, 760. 14

VERDUGO CANYON WATER COMPANY.

The waters of Verdugo Canyon are percolating waters of rather uniform flow, which escape from gravels that fill the valley of La Cañada, between the San Rafael and Verdugo hills to the south and the San Gabriel Range to the north. They drain into the lower San Fernando Valley through Verdugo Canyon, rising to the surface in a number of springs along the southern 1¾ miles of its course. The flow from these springs forms two small surface streams, one on either side of the canyon. By a court decree, handed down in November, 1871, the waters on the east side of the canyon were awarded to Theodore Verdugo and his assigns, and made appurtenant to 2,629.01 acres lying within the limits of the canyon. Since the award, portions of the tract have been sold, and there are now several owners of the east-side water. By the same decree all surplus east-side water, above that reasonably required by Verdugo and his successors in interest, was to be turned into the channel of the west-side springs and to become a part of those waters which were allotted to lands lying in the east end of the San Fernando Valley below the canyon. This west-side water was divided into 10,000 parts, and apportioned among the various interests claiming it. The division was made by time, an owner of one part being entitled to the total west-side flow for one minute of each week.

June 18, 1884, the Verdugo Canyon Water Company was organized to better effect the distribution of this west-side water by constructing and maintaining a system of pipe lines, hiring a zanjero, etc., and to develop the underflow of the canyon. The capital stock was fixed at $10,000, divided into 10,000 shares, each representing one of the original 10,000 parts of the west-side water. Three-fourths of the owners of the west-side interests joined the organization, and 7,500 shares were issued, C. E. Thom and E. M. Ross, owners of one-fourth interest, remaining outside the company. No subscriber to the capital stock of the company may hold more shares than he owns ten-thousandths of west-side water. There are 300 stockholders, each of whom receives a proportion of the total flow equal to the ratio of his stock to the total issue of 10,000 shares. Only six of these stockholders, however, receive their water directly from the company's pipe lines. The remainder have organized a number of subordinate companies. These companies and the number of ten-thousandths of west-side water which they receive are listed in the following table:

Subordinate companies receiving west-side water of Verdugo Canyon.

Verdugo Springs Water Company	666
Verdugo Pipe and Reservoir Company	1,307.5
Tropico Water Company	1,191
Independent Water Company	924.5
North Glendale Pipe and Reservoir Company	2,128
East Glendale Reservoir and Pipe Company	670
Glassell Pipe Company	613

Five of these subsidiary companies own reservoirs, and the share of each is delivered to it in a constant flow. The West Glendale Reservoir and Pipe Company and the Glassell interests do not own reservoirs, and their share of water is delivered once or twice weekly in accumulated heads. The Verdugo Canyon Water Company also delivers to C. E. Thom and E. M. Ross their proportion of canyon water, collecting from them a proportionate share of operating expenses.

The responsibility of the Verdugo Canyon Water Company ceases with the delivery of its share of water to each of the subordinate companies. The further subdivision of the water and its delivery to the individual stockholders, through the pipe lines and reservoirs of the subordinate companies, is charged for by the companies.

During the five seasons covering the years 1900 to 1904 the average annual expenses of the Verdugo Canyon Water Company were 27 cents per share. This charge covered operation, maintenance, legal fees, and other expenses, and a payment of $2,500 on the indebtedness. The total flow, surface and developed, controlled by the company varies from 65 to more than 100 inches. The maximum surface flow recorded, 171 miner's inches, was measured in August, 1890. The minimum combined surface and developed underflow, 64.2 miner's inches, was measured October 1, 1904. Other records of measurements are given below:

Measurements of Verdugo Canyon waters.

Date.	Surface flow.	Underflow diverted by dam.	Total.
	Miner's in.	*Miner's in.*	*Miner's in.*
May 14, 1904	51	26.7	77.7
August 14, 1904	45.6	19.7	65.3
May 27, 1905	77.7	23.9	101.6

Soon after the incorporation of the Verdugo Canyon Water Company, steps were taken to divert the canyon water. A masonry dam 50 feet long was built across the bed of the creek, a short distance below the tract now known as Verdugo Park. No attempt was made to reach bed rock, the base of the dam being sunk only 6 feet below the surface. From the dam about 26,000 feet of 16-, 10-, and 8-inch cement pipe were laid to the reservoirs below. Practically this same system remains in existence to-day, the only change being an extension of 500 feet of 25-inch cement main upstream to the submerged dam begun in 1895. Preparations for this latter construction had been made in 1894 by the purchase of 7⅛ acres of land, above the old diversion dam, for $2,500, all of the west-side interests joining in the purchase. Explorations for bed rock were carried out, and as they resulted favorably, construction was about to be undertaken when it was found impossible to procure a direct right of way across the canyon from the owner of the adjoining property on the east. An alternative indirect right of way was offered, however, and accepted, and construction was begun. Two hundred and forty feet of dam had been built when the channel deepened and bed rock was lost. Exploration for it resulted in an estimate that the dam could not be completed for less than $50,000. As $20,000 had already been expended, the estimate was considered prohibitive and work was stopped. This incomplete dam results in the recovery of some of the underflow, as is indicated by the table on page 136.

YIELD OF FLOWING WELLS.

In the endeavor to use tables heretofore published, for the easy determination of the yield of flowing wells when the diameter of the casing and the height of the dome are known, difficulties have been encountered, the majority of the tables extant proving inaccurate. The most satisfactory formulas known to the writer for the yield of wells discharging vertically are those of C. E. Grunsky. From these formulas, which are given below, a set of simple tables of the yield of wells flowing 250 California miner's inches or less has been compiled. These tables have proved convenient in the field work of the author of this report, and it is hoped that they may prove equally useful to others.

Grunsky's formulas for yield of flowing wells.

[Q=Gallons per minute; d=diameter; h=dome.]

When $h>d$ (spouting wells), $Q=5.35d^2\sqrt{h}$

When $h<\frac{1}{10}d$, $Q=10d\sqrt{h^3}$

When $h<d$ and $>\frac{1}{10}d$, $Q=\dfrac{10dh\sqrt{h}}{\sqrt{1+2.525\left(\frac{h}{d}\right)^2}}$

Yield of flowing wells.

[California miner's inch of 9 gallons per minute or 0.02 second foot.]

Height of dome, in inches. / Diameter of well, in inches.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.2	[illegible]	½	½	½	½	¾	1	1	1	1	1	1	1	1	1
.4	[illegible]	1	1	1	1	2	2	2	3	3	3	3	4	4	4
.6	[illegible]	1	2	2	2	3	3	4	4	5	5	6	6	7	7
.8	1	1	2	3	4	4	5	6	7	8	8	9	10	10	11
1.0	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16
1.2	1	2	4	5	7	8	9	11	13	14	16	17	19	20	21
1.4	1	2	4	6	8	10	12	14	16	18	20	22	24	25	27
1.6	1	3	5	7	10	12	15	17	19	21	24	26	29	31	34
1.8	1	3	5	8	12	14	17	20	23	25	28	31	34	36	40
2.0	1	3	6	9	13	16	19	23	26	29	32	36	40	42	46
2.2	1	3	6	11	15	18	22	26	30	34	37	41	45	49	52
2.4	1	4	7	12	16	20	25	30	34	38	42	46	50	55	59
2.6	1	4	7	13	18	22	28	32	38	42	47	51	37	61	67
2.8	1	4	8	14	19	24	31	36	42	47	52	57	63	69	75
3.0	1	4	9	15	21	26	33	40	46	51	57	63	70	76	83
3.2	1	4	10	16	22	28	35	43	50	56	62	70	77	83	90
3.4	1	4	10	17	23	30	38	46	53	60	68	77	84	91	98
3.6	1	4	11	17	24	32	41	49	57	65	73	82	91	99	107
3.8	1	4	11	18	26	34	43	52	61	70	80	89	97	106	115
4.0	1	5	11	18	27	36	46	56	65	75	85	94	103	113	125
4.2	1	5	11	19	28	38	48	58	69	80	90	100	110	121	132
4.4	1	5	12	19	29	39	50	61	73	85	96	106	117	129	140
4.6	1	5	12	20	30	41	52	64	77	90	101	112	124	138	149
4.8	1	5	12	20	31	42	54	67	81	94	106	118	131	145	156
5.0	1	5	12	21	32	44	57	70	84	97	111	124	139	153	164
5.2	1	5	12	21	33	45	59	73	87	101	116	130	146	160	172
5.4	2	5	12	22	34	46	61	76	91	106	121	136	152	168	179
5.6	2	5	13	22	34	48	62	79	94	110	126	142	157	175	188
5.8	2	5	13	23	35	49	65	81	97	114	131	148	164	181	196
6.0	2	5	13	23	36	50	67	84	100	118	136	154	172	187	206
6.2	2	5	13	24	36	51	68	86	104	121	141	159	177	196	213
6.4	2	6	14	24	37	52	70	89	107	126	146	164	185	204	222
6.6	2	6	14	24	38	53	72	91	111	130	151	170	190	210	230
6.8	2	6	14	25	39	54	73	93	114	134	155	175	197	218	237
7.0	2	6	14	25	39	56	75	96	116	138	160	181	204	225	246
7.2	2	6	14	25	40	57	76	98	119	142	164	187	210	232	....
7.4	2	6	14	26	40	58	78	100	122	146	168	193	215	240	....
7.6	2	6	15	26	41	58	79	102	124	149	173	199	221	247	....
7.8	2	6	15	26	41	59	80	104	128	152	177	204	227	....	....
8.0	2	6	15	27	42	60	81	106	130	154	182	208	233	....	....
8.2	2	6	15	27	42	60	82	108	133	157	187	212	240	....	....
8.4	2	7	15	27	43	61	83	110	136	160	191	217	247	....	....
8.6	2	7	15	28	43	62	85	111	138	163	196	221	....	....	....
8.8	2	7	15	28	44	63	86	113	140	167	200	225	....	....	....
9.0	2	7	16	28	44	63	87	114	142	170	204	229	....	....	....
9.2	2	7	16	29	45	64	88	116	144	175	207	235	....	....	....
9.4	2	7	16	29	45	65	89	117	146	178	210	241	....	....	....
9.6	2	7	16	29	46	66	90	118	148	180	213	246	....	....	....
9.8	2	7	16	30	47	67	91	119	150	184	217	251	....	....	....
10.0	2	7	17	30	47	68	92	121	153	187	220	....	....	....	....

MAPS AND TABLES.

Such information on the foothill belt as is capable of graphic presentation has been assembled in maps and tables.

The maps (Pls. III-IX, in pocket) show the lands irrigated in the foothill belt, the chief pipe and canal lines of the various irrigating companies, the pumping plants, the artesian wells, a few of the domestic wells, ground-water levels, indicated by hydrographic contours, and artesian areas past and present.

In the tables the information collected during a careful canvass of the wells of the foothill belt has been assembled. This information includes the name of the owner, the location of the well, the date of its completion, its diameter, depth, and cost, the cost of the installation where pumping machinery is in use, the use made of the water, and the amount produced. For some wells temperature data and rough determinations of the amount of solid matter in the water in parts per 100,000, as a result of measurements of the electric resistance by the Wheatstone bridge, are included.

It has not been possible to obtain all of this information for each well examined, and in many cases that collected is only approximately correct, but such facts as are known are presented.

The greater part of the data thus assembled, both in the tables and maps, has been collected by W. N. White, field assistant, to whom cordial acknowledgments are due. In assembling the material in the office for publication, both Mr. White and A. J. Fisk, jr., have assisted.

The following list of useful equivalents has been compiled by J. B. Lippincott:

USEFUL EQUIVALENTS.

1 United States gallon of water weighs 8.345 pounds.
1,000,000 gallons per day=1.54723 second-feet.
1 cent per 1,000 gallons=$3.367 per acre-foot.
1 old California miner's inch=1,728 cubic feet per day, or
$\frac{1}{50}$ second-foot, or
12,925 gallons per day, or
538.5 gallons per hour, or
630,720 cubic feet per year, or
14,478 acre-feet per year.
1 new California miner's inch=1½ cubic feet per minute, or
$\frac{1}{40}$ second-foot.
1 Colorado miner's inch=2,250 cubic feet per day, or
17,000 gallons per day (approximately).
1 second-foot=50 California miner's inches, or
38.4 Colorado miner's inches, or
450 gallons per minute, or
723.92 acre-feet per year, or
1.983471 acre-feet in 24 hours, or
59½ acre-feet in 30 days, or
646,315 gallons per day.
1 second-foot per year=13.57 inches in depth per square mile.
1 acre-foot=25.2 California miner's inches for 24 hours, or
43,560 cubic feet, or
325,851 United States gallons.
2 acre-feet in 30 days=continuous flow of 0.03⅓ second-foot.
1 cubic foot=7.4805 gallons.
1 cubic foot of water at 62° F. weighs 62.355 pounds.
1,000,000 cubic feet=23 acre-feet (approximately).
1 barrel crude oil=42 gallons.
1 barrel crude oil of 14° gravity weighs 340.6 pounds (usually taken at 341 pounds).
1 gallon crude oil weighs 8.12 pounds.
Pressure per square inch for each foot of head=0.433 pound.
Pressure in pounds per square inch × 2.31=head in feet.
Grains per gallon × 1.71=parts per 100,000 of solids.
Velocity of 1 mile per year=0.000167 foot per second.

GENERAL STATISTICS.

Flowing wells, pumping plants, irrigated area, etc., in foothill belt of southern California in 1905.

	Cucamonga quadrangle.	Pomona quadrangle.	Pasadena quadrangle.	Total.
Number of flowing wells	25	0	13	38
Number of pumping plants	107	93	168	368
Estimated investment in wells and pumping equipment	$388,839	$355,643	$448,642	$1,193,124
Estimated average output, continuous flow, second-feet	25	20	40	85
Area irrigated ... acres	21,643	17,288	16,750	55.681
Artesian area, 1905 ... square miles	3.5	0	1.3	4.8
Original artesian area ... do	4.75	1.1	2	7.6
Estimated area tillable land ... do	150	147	148	445

WELL DATA.

Wells in the foothill belt of southern California.

CUCAMONGA QUADRANGLE.

[* Cost of well and equipment combined; † yield estimated or statement of owner taken; ? doubtful. The miner's inch used in these tables is the old California miner's inch, i. e., the amount of water which flows from a 1-inch orifice under a 4-inch head; it is equal to 9 gallons per minute, 14,478 acre-feet per year, or one-fiftieth second-foot.]

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
1	D. G. Henderson	Sec. 16, T. 1 N., R. 6 W	N-6	1883		2,300					Tunnel			Irrigation	† 5
2	Sexton Bros	Sec. 5, T. 1 S., R. 6 W.	M-10	1901	Bored, 10-inch	1,280	980	1,000?				$4,000.00?		Not used	
3	Joseph Gecman	Sec. 20, T. 1 S., R. 6 W.	M-12, 13	1886	Bored, 2-inch	1,040	810	300			Wind	300.00	*80.00	Domestic	
4	H. Schoenfelder	Sec. 33, T. 1 S., R. 6 W.	N-14	1896	Dug, 3½ by 2½ foot.	910	768	160			do	250.00	90.00	do	
5	Riverside Vineyard Co.	Sec. 4, T. 2 S., R. 6 W.	M-15	1900	Bored, 12-inch	840	740	400			Steam	500.00	7,500.00	Irrigation	† 175
6	H. Maittral	Sec. 32, T. 1 S., R. 6 W.	M-15	1896	Bored, 7-inch	850	698	230			Wind			Domestic; stock.	
7	Riverside Vineyard Co.	Sec. 4, T. 2 S., R. 6 W.	M-16	1889	Bored, 10-inch	805	685	176			do	250.00	100.00	do	
8	do	do	M-16	1895	Bored, 8-inch	798	684	150			do	200.00	75.00	Stock	
9	Union school district.	do	M-16	1894	Bored, 7-inch	785	700	145			do	250.00	75.00	Domestic	
10	I. N. Van Nuys	Sec. 10, T. 2 S., R. 6 W.	M-17	1884	do	740	650	150			do	300.00	75.00	Domestic; stock.	
11	do	do	N-16, 17	1884	do	775	687	143			Not raised	275.00	75.00	Not used	
12	G. M. Laren	Sec. 8, T. 2 S., R. 6 W.	M-17	1894	do	770	686	148			Wind			Domestic	
13	R. L. Summerwell	do	L-16	1895	do	780	687	140			do	200.00	100.00	Not used	
14	F. A. Gallwas	Sec. 6, T. 2 S., R. 6 W.	K-16	1892	do	790	671	154			do	200.00	100.00	Domestic; stock.	
15	C. Carroll	Sec. 7, T. 2 S., R. 6 W.	L-16	1890	do	770	686	100			Not raised			Not used	
16	A. T. Galloway	Sec. 6, T. 2 S., R. 6 W.	L-16	1896	do	790	689	139			Wind	225.00	75.00	Domestic	
17	R. T. Garner	do	L-15	1885	do	840	703	164			Hand	300.00		do	
18	A. T. Galloway	do	L-16	1896	do	825	687	140						Not used	

19	Mrs. M. L. Johnson	do	K-15	1892	do	840	703	164			Wind	225.00	100.00	Domestic; stock	
20	A. La Fourcade	Sec. 29, T. 1 S., R. 6 W.	L-14	1889	Bored, 8-inch	965	645	400			do	700.00	100.00	do	
21	Smith Bros	Sec. 7, T. 1 S., R. 6 W.	L-11	1903	Dug, 4½ by 4½ foot, 158 feet; bored, 12-inch, 492 feet.	1,125	895	650	23		Steam	3,000.00		Irrigation	†15
22	Cucamonga winery	Sec. 11, T. 1 S., R. 7 W.	J-11	1903	Bored, 5-inch	1,122	822	497	21		Gas	2,500.00	3,000.00	Winery	†3
22a	do	do	J-11	1903	Bored, 12-inch	1,122	805	540	21		do	3,000.00		do	†5
23	Colonel Post	Sec. 18, T. 1 S., R. 7 W.	K-11		Bored, 7-inch	1,110	820	420						Not used	
24	Benton Ballou	Sec. 26, T. 1 S., R. 7 W.	J-14	1892	do	885	756	158	23		Wind	250.00	100.00	Domestic; stock	
25	Mrs. Martha Collins	Sec. 35, T. 1 S., R. 7 W.	J-14	1884	do	865	705	180	23		do	300.00	100.00	do	
26	A. T. Hamilton	do	J-14	1888	do	880	702	252			do	640.00	150.00	do	
27	Thos. Monks	do	J-15	1900	do	845	717	164	22		do	250.00	100.00	do	
28	J. R. Merrill	Sec. 2, T. 2 S., R. 7 W.	J-16	1901	do	830	711	151	21		do	250.00	75.00	do	
29	F. H. Hollister	Sec. 11, T. 2 S., R. 7 W.	J-16	1892	do	785	673	148	22		Hand	180.00	38.00	Not used	
30	L. H. Farron	do	J-16		do	785	676	125	22					do	
31	R. W. Henderson	Sec. 12, T. 2 S., R. 7 W.	J-16	1892	do	790	695	117	23		Wind	225.00	125.00	Domestic; stock	
32	Wm. B. Jackson	Sec. 11, T. 2 S., R. 7 W.	J-17	1901	do	740	663	113	23		do	152.00	125.00	do	
33	D. McDougall estate.	Sec. 14, T. 2 S., R. 7 W.	I-17	1896	do	730	678	81				75.00	75.00	Not used	
34	L. Bergstrom	Sec. 10, T. 2 S., R. 7 W.	I-17	1896	do	735	680	79			Wind	100.00	90.00	do	
35	J. Martinas	do	I-17	1896		740	688	100							
36	A. H. Blakeley	do	I-17	1892	Bored, 7-inch	755	695	75	22		Wind	100.00	85.00	Domestic; stock	
37	George W. Ingram	do	I-17	1892	do	750	689	100	22		do	175.00	150.00	Domestic	
38	Charles Lambe	do	I-17	1896	do	735	677	112	22		do	95.00	125.00	Domestic; stock	
39	Torence Pratt	do	I-17	1896	do	745	684	86			do			Not used	
40	William Riggs	Sec. 11, T. 2 S., R. 7 W.	I-17	1889	do	760	681	99			Not raised			do	
41	Arthur Pooley	Sec. 10, T. 2 S., R. 7 W.	I-17	1897	do	765	690	88	20		Wind	100.00	100.00	Domestic	
42	Mr. Searls	do	I-16	1893	do	775	Dry.	61							
43	Mountain View district school.	Sec. 2, T. 2 S., R. 7 W.	I-16	1887	do	810	700	140	21		Wind	250.00	175.00	Domestic	
44	D. F. Stoner	Sec. 3, T. 2 S., R. 7 W.	I-16	1894	do	825	710	165	21		do			do	
45	George Andrews	Sec. 33, T. 1 S., R. 7 W.	H-14		do	890	760	138			do			Not used	
46	Mr. Eason	do	H-14		do	880	756	130						do	
47	do	Sec. 28, T. 1 S., R. 7 W.	H-14	1901	Bored, 10-inch	930	Dry.	173						do	
48	James Quibell	Sec. 27, T. 1 S., R. 7 W.	I-14	1902	do	915	770	211			Gas	371.00	1,350.00	Irrigation	†15

Wells in the foothill belt of southern California—Continued.

CUCAMONGA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
49	Mr. Southworth	Sec. 32, T. 1 N., R. 6 W.	L-9			1,325	Dry.	320							
50	J. Bennett	Sec. 1, T. 1 S., R. 7 W.	K-10			1,210	Dry.	200							
51	O. Bartell	Sec. 8, T. 1 S., R. 6 W.	M-10		Dug, 4 by 4 foot.	1,210	Dry.	200							
52	Mrs. Louis Smith	Cucamonga	I-11	1899	Dug, 3 by 3 foot.	1,175	Dry.	149				$200.00			
53	Old Settlers Water Co.	do	I-10	1902	Bored, 15-inch, 180 feet; 12-inch, 120 feet; 10-inch, 48 feet.	1,315	1,271	348	23		Gas	1,047.00	$1,900.00	Irrigation	†32
54	Sunset Water Co.	do	I-9	1901	Dug, 5 by 7 foot, 110 feet; bored, 15-inch, 200 feet; 12-inch, 555 feet.	1,395	1,305	865			Electric motor	4,000.00	2,500.00	do	†30
55	do	do	I-9	1900	Dug, 4 by 6 foot; bored, 12-inch.	1,410	1,324	190						Not used	
56	Hermosa Water Co.	do	I-8	1901	Bored, 10-inch.	1,520	1,300	275			Gas	800.00	2,500.00	Irrigation	†30
58	Upland Water Co.	do	H-9	1901	Dug, 5 by 7 foot, 110 feet; 7 by 14 foot, 63 feet; bored, 12-inch, 261 feet.	1,560	1,387	434			Steam		3,400.00	do	†40
59	Cucamonga Water Co.	do	H-9	1897	Bored, 12-inch, 381 feet; 8-inch, 100 feet.	1,420	1,343	541	20	71		1,500.00		Not used	
60	do	do	H-9	1897	Dug, 4 by 6 foot, 114 feet; bored, 12-inch, 105 feet; 8-inch, 196 feet.	1,457	1,355	479	21	72	Electric motor			Irrigation	†25

61	do	do	I-9	1899	Bored, 9½-inch	1,358	1,271	456	17	72	Flows into tunnel.				
62	do	do	I-10	1899	Dug, 40 feet; bored, 9½-inch, 464 feet.	1,346	1,265	504			Electric motor			do	†50
63	do	do	I-9	1899	Dug, 47 feet; bored, 9½-inch, 386 feet.	1,389	1,292	433	17	72	Flows into tunnel.			do	†3
64	do	do	I-10	1899	Dug, 90 feet; bored, 9½-inch, 338 feet.	1,395	1,298	428		73	do			do	†4
65	do	do	I-9	1899	Bored, 9½-inch	1,376	1,276	547			do			do	†2
66	do	do	I-9	1899	do	1,379	1,283	287			do			do	†4
68	do	do	G-10	1897	do	1,388	1,303	371						Not used	
69	do	do	G-10	1899	Bored, 12-inch, 366 feet; 10-inch, 300 feet.	1,374	1,294	660		64	Flows into tunnel.			Irrigation	
70	do	do	G-10	1904	Bored, 10-inch	1,395	1,299	540			do			do	†35
71	do	do	G-10	1901	Bored, 15-inch, 224 feet; 12-inch, 296 feet.	1,398	1,300	520			do			do	†40
72	do	do	G-10											Not used	
73	San Antonio Water Co.	do	G-9	1901	Dug, 5 by 8 foot, 110 feet; bored, 12-inch, 528 feet.	1,488	1,365	638		62	Electric motor			Domestic; irrigation.	†75
74	do	do	G-9	1901	Dug, 125 feet; bored, 12-inch, 499 feet.	1,483	1,351	624	20	62	do			Irrigation	†75
75	do	do	G-9	1898	Dug, 124 feet; bored, 12-inch, 516 feet.	1,482	1,352	640	19	62	do			do	†75
76	do	do	G, H-9	1901	Dug, 126 feet; bored, 10-inch, 414 feet.	1,403	1,361	540	20	62	do			Domestic; irrigation.	†75
77	do	do	H-9	1901	Dug, 130 feet; bored, 7-inch, 270 feet.	1,495	1,365	400			do			Irrigation	†75
78	do	do	H-9		Dug, 103 feet; bored, 9½-inch.	1,480	1,364		21	60	do			do	† 30
79	do	do	H-9	1900	Dug, 142 feet; bored, 12-inch, 507 feet (2 wells).	1,495	1,356	649		70	do			do	† 150
80	do	do	G-10	1902	Bored, 15-inch	1,410	1,310			64	do			do	† 175
85	Stewart & Co	do	E-8	1898	Dug, 3 by 5 foot.	1,805	Dry.	250							
86	Canyon Ridge Water Co.	do	E-8	1898	Dug, 4 by 5 foot.	1,815	1,700	165			Gas			Irrigation	† 25
87	S. A. Bard	do	E-8	1896	Dug, 3 by 6 foot.	1,820	1,710	160	23		do		1,200.00	do	† 20
88	San Antonio Water Co.	do	E-8	1903	Dug, 5 by 12 foot, 182 feet; bored, 14-inch, 228 feet.	1,820	1,710	410				2,000.00		do	

Wells in the foothill belt of southern California—Continued.

CUCAMONGA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
89	San Antonio Water Co.	Cucamonga	E-9		Dug	1,875	1,705	212						Not used	
90	Colonel Paul and C. D. Adams.	do	E-8	1897	Dug, 4 by 5 foot.	1,885	1,700	220			Electric motor.			Irrigation	†16
92	James Illingworth	do	E-7	1901	Dug, 3 by 5 foot.	2,160	2,026	143		61	Wind	$400.00	$125.00	Domestic; irrigation.	
94	San Antonio Water Co.	Sec. 25, T. 1 N., R. 8 W.	E-9	1895	Dug, 4 by 4 foot.	1,718	Dry.	100				500.00		No water	
97	do	do	E-8, 9	1895	do	1,745	Dry.	122				600.00		do	
98	do	do	E-9	1895		1,695	Dry.	102						do	
99	Citizens' Bank of Ontario.	Cucamonga	F-9	1898	Dug, 5 by 5 foot.	1,535	Dry.	275							
101	William Littlewood.	do	E-9	1899	Dug, 4 by 5 foot.	1,590	Dry.	300				700.00			
102	J. W. Mabb	do	F-9		Dug, 3 by 4½ foot.	1,525	Dry.	128							
103	Kirk Farlow Water Co.	do	F-8, 9		Dug, 3 by 5 foot.	1,645	Dry.	204							
104	Doctor Fargo	do	F-7		Dug, 4 by 6 foot.	1,925	Dry.	400							
105	San Antonio Water Co.	do	G-7	1896	Dug						Tunnel	80,000.00?		Irrigation	†10
108	Mr. Hemen	Sec. 27, T. 1 N., R. 8 W.	C-8	1896	do	1,735	1,697	40			Wind			Stock	
109	Mountain View Water Co.	Sec. 2, T. 1 N., R. 8 W.	D-10	1899	Dug, 5 by 6 foot, 63 feet; bored, 10-inch, 62 feet.	1,412	1,354	125			Gas	750.00	475.00	Irrigation	†15
110	do	do	D-10	1899	Dug, 5 by 6 foot, 93 feet; bored, 10-inch, 47 feet.	1,410	1,354	140			do	1,000.00	750.00	do	†30
111	do	do	C-10	1892	Dug, 4 by 5 foot, 71 feet; bored, 8-inch, 42 feet.	1,390	1,352	113		62	Flows into tunnel.			do	
112	B. K. Brant	Sec. 12, T. 1 N., R. 8 W.	D-10	1900	Dug, 4 by 6 foot.	1,350	Dry.	507				2,000.00		do	
113	I. L. Means	Sec. 15, T. 1 S., R. 8 W.	C-12	1900	Bored, 10-inch	1,050	783?	331			Gas	900.00	2,000.00	do	†30
113a	do	do	C-12	1901	Bored, 14-inch	1,050	782?	370			do	1,000.00			

114	M. W. Cobban	Sec. 22, T. 1 S., R. 8 W.	C-13	1899	Bored, 7-inch	1,005	800	260	20		Wind	700.00	175.00	Domestic	
115	W. L. Holmes	do	C-13	1903	Bored, 10-inch	965	777	280	19	64		640.00		Not installed	
116	F. E. Jones	Sec. 26, T. 1 S., R. 8 W.	C-14	1902	Bored, 7-inch	945	773	408			Wind	700.00	350.00	Domestic; irrigation.	
117	Mr. McLaughlin	Sec. 23, T. 1 S., R. 8 W.	D-13		do	980	775	208			do			Not used	
118	Mrs. M. H. Fitch	do	D-13		do	995	785	250	22	58	do				
119	Fortier, Green & Hill Water Co.	do	D-13	1899	Bored, 10-inch	1,015	783	334	21	59	Gas	800.00	1,700.00	Irrigation	† 20
120	J. Sternberg	do	D-13	1898	do	990	780	308	21	62	do	800.00	1,500.00	Domestic; irrigation	† 10
121	Crawford Bros	Sec. 26, T. 1 S., R. 8 W.	D-13	1899	Bored, 10½-inch (2 wells).	980	775	325	20		do	800.00	5,000.00	Irrigation	† 35
122	J. Sullivan	Sec. 25, T. 1 S., R. 8 W.	E-13	1903	Bored, 9½-inch	990	770	335	19		Electric motor	815.00		do	† 20
123	A. L. King	do	E-13	1899	Bored, 12-inch	995	771	476	21		Gas	1,000.00	1,700.00	do	† 17
124	Lyman Stewart	Sec. 24, T. 1 S., R. 8 W.	E-12	1901	Dug, 6 by 8 foot, 320 feet; bored, 12-inch, 180 feet.	1,085	780	500			Steam	5,000.00	5,000.00	do	† 20
125	George Hocknell	do	E-13	1900	Bored, 10-inch	1,043	767	320			Not raised	850.00		Not used	
126	George C. Hagar	Sec. 21, T. 1 S., R. 7 W.	H-13	1895	Dug, 4 by 4 foot, 176 feet; bored, 7-inch, 44 feet.	980	782	220			do			do	
127	R. H. Hannah	Santa Ana del Chino.	F-14	1900	Bored, 10-inch	931	758	211			Wind	350.00	125.00	Domestic; irrigation.	
128	James H. Sauerwein	Sec. 1, T. 1 S., R. 8 W.	E-9	1894	Dug, 3 by 5 foot	1,540	Dry.	300				2,000.00		No water	
129	Doctor Turner	Santa Ana del Chino.	D-15		Bored, 10-inch (2 wells).	865	750	125	27		Wind			Irrigation	
130	Edward Chapman	do	D-16		Bored, 7-inch	810	746	150	27		do			Domestic; stock	
131	F. E. Schaad	do	D-16	1894	do	785	739	375	30	64	Gas			Irrigation	
132	H. C. Roberts	do	D-16	1899	do	775	739	126	19	67	do	500.00	300.00	Domestic	
133	Stephen Bush	do	D-16	1894	do	770	728	53			Wind		75.00	do	
134	J. B. Mart	do	D-16	1900	do	765	729	160	20	64	do			do	
135	C. W. Brenell	do	D-17	1903	do	740	717	112			do	100.00	75.00	do	
136	H. E. Benjaman	do	D-17	1901	do	725	700	160		68	do	200.00	100.00	do	
137	Mrs. E. G. Tateng	do	D-17	1897	Dug, 4 by 4 foot.	705	682	25	21		do			do	
138	C. Nabakowski	do	E-17	1900	Bored, 7-inch	705	701	255						Not used	
139	American Beet and Sugar Co.	do	E-17			695	695	300		69	Artesian			do	
140	J. T. Curlee	do	E-17	1900	Driven, 2-inch	715	704	13	19	68	Hand			Domestic	
141	W. C. Rightmier	do	E-17	1894	Bored, 7-inch	690	690	148	19	67	Gas, artesian	240.00	415.75	Irrigation	[a]† 22
142	W. J. Schaefer	do	E-17	1897	do	695	695	323			do	700.00	700.75	Domestic; irrigation.	[b]† 4
143	L. Anderson	do	D-17	1900	do	690	690	243			Artesian			Irrigation	4
144	W. C. Rightmier	do	D-17	1901	do	680	680	126			do			do	5
145	Mr. Dunn	do	D-17		do	675			19	67	do			Domestic; stock	
146	Z. Wilkison	do	D-16		Dug, 3½ by 3½ foot.	760	721	41	22		Hand			Domestic	

[a] Pumped.

[b] Flow.

Wells in the foothill belt of southern California—Continued.

CUCAMONGA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
147	F. M. Hildebrand	Santa Ana del Chino.	D-16	1903	Bored, 7-inch	745	721	138	23		Gas, wind	$160.00	$230.00	Domestic; irrigation.	
148	State Experiment Station.	do	C-15, 14	1899	do	855	761	142	23		Wind			Domestic; stock.	
149	W. McCain	do	C-15	1895	do	825	733	162+			do			Domestic; irrigation.	
150	A. Armstrong	do	C-15	1900	Bored, 10-inch	830	740	412			Gas		2,000.00	do	† 70
151	J. M. Mitchell	do	C, D-15	1900	Bored, 12-inch	860	750	336			do	800.00	1,975.00	Irrigation	† 30
152	Mrs. L. D. Greene	do	C-17	1896	Bored, 7-inch	720	709	135			Wind			Domestic	
153	Victor Gustafson	do	C-16	1902	Bored, 10-inch	735	719	640			Gas	1,500.00	1,000.00	Irrigation	† 60
154	O. W. Lorbeer	do	C-16	1888	do	755	727	973						Not used	
155	George E. Hollister	do	C-16	1903	Bored, 7½-inch	756	723	180	19		Wind	250.00	85.00	Domestic; irrigation.	
156	Black Bros. & Woodhead.	do	C-16	1903	Bored, 10-inch	743	725	718			Gas	1,900.00	1,000.00	Irrigation	† 80
157	Mrs. E. M. Day	do	C-16	1899	Bored, 7-inch	725	716	314				500.00		Not installed	
158	I. Bristol	do	B-16	1891	Bored, 4-inch	720	717	150			Wind	225.00	75.00	Domestic	
159	Mrs. M. A. Murdock	do	B-16	1899	Bored, 7-inch	715	715	247			Gas	500.00	800.00	Irrigation	
160	F. E. Reimers	do	B-16	1902	do	780	734	65			Wind	85.00	75.00	Domestic	
161	M. Payne	do	B-15	1892	do	780	734	50			do	62.50	90.00	do	
162	W. E. Jones	do	B-15	1892	Bored	785	742	900			Gas			Irrigation	† 35
163	John O'Donnell	do	B-15	1899	Bored, 10-inch	810	755	374	20	66	do		2,000.00	do	† 80
164	do	do	B-15	1889	do	795	742	160			Wind			Domestic; stock.	
165	American Beet and Sugar Co.	do	D-17		Bored, 9-inch	700	694	319			Compressed air			Factory	
165a	do	do	D-17		do	700	694	138			do			do	
166	do	do	D-17		Bored	695	695?	309			do			do	
166a	do	do	D-17		do	695	695?	297			do			do	
167	do	do	D-17		do	690	690	481			Compressed air, artesian.			do	
168	do	do	D-17		Bored, 8-inch	700	696?	250			Compressed air			do	
168a	do	do	D-17		Bored, 7-inch	700	696?	223			do			do	
169	do	do	D-17	1897	Bored, 8-inch	690	690?	315			do			do	
169a	do	do	D-17	1897	Bored	690	690	250			do			do	
170	do	do	B-16		Bored (5 wells)	735	720?	250–383			Not raised			Not used	

171	do.	do.	B-17		Bored	705	701	260			Compressed air			Factory	
172	Chino Land and Water Co.	do.	B-17	1899	Bored, 9½-inch (6 wells).	665	665	100-140			Artesian			Irrigation	103
172a	do.	do.	B-17	1903	Bored, 9½ to 13 inch (2 wells).	665	665	100-140			do.				
172b	do.	do.	B-17	1903	Bored, 14-inch	665	665	140			do.				
172c	do.	do.	B-17	1903	do.	665	665	300			do.				
173	do.	do.	B-16		Bored, 10-inch	715	715	345			do.			Domestic; stock.	5
173a	do.	do.	B-16		do.	715	715	150			do.				
174	H. W. Trayermuth	Sec. 28, T. 1 S., R. 8 W.	B-14	1897	Bored, 6-inch	885	776	175	22		Wind			Domestic	
175	S. L. Crane	Sec. 29, T. 1 S., R. 8 W.	A-14	1884	Bored, 7-inch	865	777	90			do.			do.	
176	Mrs. M. E. Porter	Sec. 28, T. 1 S., R. 8 W.	B-14	1886	do.	865	735	160	21		do.			do.	
177	Mrs. Tiegs	do.	B-14		Bored, 10-inch	835	749	341			Not raised			Not used	
178	J. O'Donnell	Santa Ana del Chino.	B-15		Bored, 7-inch	840	752	174			Wind			Irrigation	
179	J. F. Mast	Sec. 28, T. 1 S., R. 8 W.	B-14		Bored, 10-inch	870	764	150	21		do.			Domestic; irrigation.	
180	M. E. Foster	do.	C-14	1895	Bored, 7-inch	860	769	106			do.			Domestic	
181	R. Reimers	do.	B-16	1894	do.	770	737	65			do.	75.00	60.00	do.	
182	W. D. McCrosky	do.	B-16	1891	Bored, 4-inch	760	734	60		66	do.			do.	
183	McCrosky & Bowler	do.	B-16		Bored, 10-inch	745	727	400						Not installed	
184	G. Y. Robertson	do.	B-16	1898	do.	720	715	160	19	67	Gas	250.00	1,000.00	Irrigation	† 40
185	George J. Weigle	San Jose	A-16	1899	Dug, 25 feet; bored, 9-inch, 280 feet.	765	743	305			do.	500.00	1,000.00	do.	† 50
186	R. M. Thurman	do.	B-16	1900	Bored, 9½-inch	770	741	380			do.			do.	† 75
187	J. J. Allan	do.	A-15	1899	Bored, 10-inch	780	744	346			do.	600.00	1,500.00	do.	† 75
188	B. F. Whipp	do.	A-15	1897	do.	785	745	180	18		do.			do.	† 60
189	Humes & Gallup	do.	A-15	1901	Bored, 9-inch	785	745	379			do.			do.	† 60
190	N. W. Miller	do.	A-15	1898	Bored, 9½-inch	790	753	245			do.	440.00	1,230.00	do.	† 50
191	C. G. Taylor	do.	B-15	1888	Bored, 7-inch	790	752	275			Wind			Domestic	
192	Van Syke & Wickersham.	do.	B-15	1900	Bored, 13-inch	805	755	434	19		Gas	1,300.00	1,700.00	Irrigation	† 76
193	Cobb, Walls, Landon & Co.	do.	A-15	1898	Bored, 10-inch	800	760	400			do.	1,000.00	2,100.00	do.	† 60
194	Mrs. Edgar	do.	A-14	1903	do.	845	773				Wind			Domestic	
195	Sanford Ballou	do.	A-14	1884	Bored, 7-inch	855	777	174			do.	300.00		do.	
196	R. A. Krause	do.	A-14		do.	845	772	178	16		do.			do.	
197	T. E. Seagoe	do.	A-14	1890	do.	830	Dry.	70						No water	
198	J. J. Gorman	do.	A-14	1886	do.	825	763	116	19		Wind			Domestic	
199	G. W. Harp	do.	D-14		do.	843	768	120			do.			do.	
200	E. Goytte	do.	B-14	1892	do.	860	Dry?	78						No water	
201	J. J. White	do.	A-14	1884	do.	830	773	67			Wind			Domestic	
202	H. B. Hansen	do.	A-14	1884	do.	825	771	57			do.			Not used	
203	J. W. Snedaker	do.	A-15		do.	810	764	67			do.			Domestic	
204	Charles Peterson	do.	A-15	1896	do.	820	763	73			do.			do.	
205	J. A. Walz	do.	A-15	1884	do.	815	761	64	25		do.	99.00	70.00	do.	
206	W. M. Niebel	Santa Ana del Chino.	B-16		do.	765	736		22		do.			do.	

Wells in the foothill belt of southern California—Continued.

CUCAMONGA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches.)
207	V. DesNoyers	Santa Ana del Chino.	B-16	1899	Bored, 10-inch	730	723	224	17	....	Gas	$500.00	$800.00	Irrigation	†35
208	F. B. Troxell	do	B-16	1893	Bored, 4-inch	720	720	160	18	66	Artesian	300.00	....	Domestic; irrigation.	4
209	Louis Lockenour	do	B-17	1897	Bored, 7-inch	685	685	160	19	67	do			Irrigation	†3
210	J. Wire	do	B-17	1901	do	685	685	156	....	....	do	300.00		do	†40
211	George Beck	do	B-16	1901	Bored, 10-inch	710	710	220	18	69	do	425.00		do	†50
212	Mr. McKinley	do	B-16		do	710	710	140	20	69	do			do	†30
213	Mr. Marion	do	B-16	1899	Bored, 8-inch	720	720	198	19	69	do	400.00		do	†20
214	C. P. Brown	do	B-16		Bored, 9½-inch	730	722	160						Not used	
215	A. L. Tufs	do	B-16	1891	Bored, 10-inch	730	722	357				727.00		do	
216	Bowler Bros	do	B-17	1896	Bored, 7-inch	680	680	139	18	68	Artesian	200.00		Irrigation	†35
217	R. J. Stewart	do	B-17	1902	do	675	675	124			do			do	
218	Chino Land and Water Co.	do	B-17			665	665	180	17	68	do			Stock	
219	Mrs. F. Fabian	do	C-17	1897	Bored, 7-inch	670	670	255	19	68	do			Irrigation	†8
220	American Beet and Sugar Co.	do	C-17			675	675	140	20		do			Stock	
221	W. P. Brown	do	C-17	1897	Bored, 7-inch	685	685	311			do			Irrigation	
222	B. Ross	do	C-17		Bored, 10-inch	690	690	300	17	67	do			do	†20
223	S. H. Adams	do	B-16	1902	Bored, 7-inch	715	715	256	19	65	do	325.00		do	4
224	A. J. Morrison	do	B-17	1899	do	675	675	250	18	68	do	600.00		do	†20
225	Charles Mason	do	C-17		do	675	675	160			do			Stock; irrigation	
226	H. F. Haman	do	C-16	1900	do	758	728	347	17	65	Gas	500.00	750.00	Irrigation	†20
227	John Boesch, jr	do	C-16	1901	do	765	729	95			Wind	150.00	85.00	Domestic	
228	John Fintel	do	C-16	1901	do	775	731	68	22	63	Hand	75.00	20.00	do	
229	C. A. Mosher	do	C-15		do	790	739	80			Wind			do	
230		do	C-15		Dug, 4 by 5 foot	820	761	62	20	64	do			do	
231	F. W. Olmstead	Sec. 22, T. 1 S., R. 8 W.	C-13	1901	Bored, 10-inch	945	785	320			Gas	700.00	2,800.00	Irrigation	†20
232	Mrs. J. Cooley	San Jose	B-13	1896	Bored, 4-inch	930	782	170			Not raised			Not used	
233	Edward Gilson	do	B-13	1898?	Bored, 8-inch	940	809	200	17	62	Gas	300.00	600.00	Domestic	†7
234	M. Baldridge	do	B-13	1898	do	930	783	250			do	400.00	1,300.00	Irrigation	†10
235	W. N. Hendricks	do	B-12	1900	Bored, 10-inch	1,085	971	129			Not raised	250.00		Not used	
236	Stoddard, Hill & Tuttle.	do	B-12	1901	Bored, 14-inch	1,075	964	280			Compressed air.	600.00	1,000.00	Irrigation	40
236a	do	do	B-12	1901	do	1,075	964	205							

237	do	do	B-12	1901	do	1,070	954	268			do	600.00		do	†40
237a	do	do	B-12	1901	do	1,070	954	270			do				
238	W. J. Warden	do	B-12	1897	Bored, 10-inch	1,065	952	187	10		Not raised	1,000.00		Not used	
238a	do	do	B-12	1897	do	1,065	952	115	10		do			do	
238b	do	do	B-12	1897	do	1,065	972	178	10		Gas		800.00	Irrigation	†20
239	John Miller	do	B-12	1898	do	1,045	942	172	20	63	do	500.00	1,500.00	do	†15
240	George H. Miller	do	B-12	1899	do	1,085	972	200	21	64	do	500.00	1,000.00	do	†15
241	G. F. Ferris	do	B-11	1892	Bored, 7-inch	1,100	872	190			Wind			Not used	
242	San Antonio Water Co.	do	B-11		Bored, 12-inch	1,121	966	558						do	
242a	do	do	B-11		do	1,121	966	535			Electric motor			Irrigation	†27
243	do	do	B-11		Bored	1,105	1,033				do			do	†55
244	do	do	B-11, 12		Dug, 7 by 10 foot.	1,100	1,031		20	58	Not raised			Not used	
245	Bartlett Bros.	do	B-11	1899	Bored, 10-inch	1,115	965	200			Gas	472.00	1,200.00	Irrigation	
246	H. R. Hawley	do	B-12		Bored	1,100	1,028				Not raised			Not used	
247	Del Monte Irrigation Co.	do	B, C-11	1886	Bored, 7-inch	1,135	1,065	275		62	Compressed air	750.00	15,000.00	Irrigation	†60
247a	do	do	B, C-11	1902	Bored, 12-inch	1,135	1,065	300			do	750.00			
248	do	do	C-11	1902	do	1,130?	1,060?	300		62	do	750.00			†75
248a	do	do	C-11	1903	Bored, 14-inch	1,135?	1,065?	400		62	do	1,200.00			
249	do	do	B, C-11	1888	Bored, 7-inch	1,130	1,060	225			do	700.00			35
249a	do	do	B, C-11	1888	do	1,135	1,065	160			do	550.00			
250	R. Bieley	do	C-11	1900	Bored, 10-inch	1,155	1,071	117			Wind			Domestic; stock	
251	George Jencks	Sec. 10, T. 1 S., R. 8 W	C-11	1901	do	1,230	1,089	175			Gas	400.00	600.00	Stock; irrigation	†5 †25
252	C. N. Brundage	do	B-12	1897	Bored, 14-inch	1,060	954	310	21		Electric motor	250.00	1,200.00	Irrigation	
253	Garlock, Phillips & Loop.	San Jose	B-11	1882	Dug, 8 by 10 foot, 50 feet; bored, 12-inch, 90 feet.	1,165	1,080	140			Steam	350.00		do	†20
254	Del Monte Irrigation Co.	Sec. 9, T. 1 S., R. 8 W.	B-11	1899	Dug, 5 by 8 foot, 106 feet; bored, 10-inch, 119 feet.	1,180	1,100	225			Electric motor	600.00	1,700.00	do	†60
255	A. T. Currier	San Jose	A-11	1895	Bored, 10-inch	1,175	1,040	310			Gas			do	†15
256	L. Brosseau	do	A-12	1894	Bored, 7-inch	1,070	Dry.	98							
257	Del Monte Irrigation Co.	Sec. 9, T. 1 S., R. 8 W.	B-11	1899	Bored, 10-inch (3 wells).	1,190	1,110	225			Compressed air	1,800.00	(a)	do	†50
258	Dr. M. B. Cambell	San Jose	B-11		Bored	1,170	1,018	300			Gas			do	†20
259	John Beck	Sec. 9, T. 1 S., R. 8 W.	B-11		Bored, 7-inch	1,215	1,100		17		Wind			Domestic	
260	G. G. Charlton	do	B-10	1899	Dug, 138 feet; bored, 9½-inch, 222 feet.	1,245	1,101	360			Steam	900.00	7,000.00	Irrigation	†30
261	A. W. Town	Sec. 4, T. 1 S., R. 8 W.	B-10	1886	Bored, 6-inch	1,240	1,090	320			Wind		40.00	Domestic	
262	do	do	B-10	1902	Bored, 12-inch	1,280	1,105	320			Gas	1,000.00	2,000.00	Irrigation	15
263	C. Siever	do	B-10	1895	Dug, 70 feet; bored, 9½-inch, 224 feet.	1,350	1,275	294			Tunnel			Not used	

[a] Connected with plants Nos. 247–249.

Wells in the foothill belt of southern California—Continued.

CUCAMONGA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
264	Consolidated Water Co.	Sec. 3, T. 1 S., R. 8 W.	C-10	......	Bored, 10-inch	1,300	1,204	200?	....	....	Flow into tunnel.	....	....	Domestic	†70
265	Ontario Water Co.	do	C-10	1900	Bored, 10-inch (2 wells).	1,265?	1,224?	160	....	....	Compressed air.	$2,400.00		Irrigation	.....
265a	do	do	C-10	1900	Bored, 10-inch	1,265?	1,224?	225	....	....	do		$5,200.00		35
265b	do	do	C-10	1900	do	1,285?	1,225?	225	....	....	do				.....
265c	do	do	C-10	1900	do	1,270?	1,223?	225	....	....	do	2,400.00			.....
265e	do	do	C-10	1900	do	1,300?	......	225	....	....	do				35
265	do	do	C-10	1901	do	1,305?	1,233?	200	....	....	do				.....
266	Citizens' Light and Power Co.	Sec. 33, T. 1 N., R. 8 W.	B-9	1903	Bored, 12-inch	1,370	1,217	385	21	64	Gas	1,400.00	3,000.00	Domestic; irrigation.	†30
267	Martin Bros	do	B-9	1899	Dug, 4 by 4 foot.	1,390	1,344	70	23	....	Wind	200.00	125.00	Irrigation	†1
268	do	do	B-9	1902	Dug, 3½ by 3½ foot, 106 feet; bored, 12-inch, 261 feet.	1,380	1,205	367	19	70	Gas	1,200.00	2,200.00	do	†25
269	C. C. Johnson	do	B-9	1903	Dug, 3 by 3 foot.	1,345	1,217	130	21	....	Wind	....	....	Domestic; irrigation.	.....
270	B. E. Street	do	B-9	1899	Dug, 100 feet; bored, 9-inch, 167 feet.	1,325	1,225?	267	....	....	Gas	800.00	200.00	Irrigation	2½
271	Claremont Cooperative Water Co.	Sec. 32, T. 1 N., R. 8 W.	A-9	1900	Bored, 12-inch	1,265	1,200	277	....	....	do	1,000.00	2,000.00	do	35
272	L. C. Pitzer	Sec. 5, T. 1 N., R. 8 W.	A-9	1903	Dug, 3 by 5 foot, 50 feet; bored, 14-inch; 370 feet.	1,270	1,200	420	....	....	do	1,500.00	3,500.00	do	†35
273	Seth Richards Orange Grove Co.	do	A-9	1899	Bored, 10-inch	1,255	1,197	305	....	....	Compressed air.	(*a*)	....	do	†40
274	Prof. Sumner	do	A-10	1897	Bored, 12-inch	1,250	1,215	275	....	....	Gas	750.00	1,600.00	do	†25
275	Schesler & Soaper	do	A-10	1902	Dug, 160 feet; bored, 10-inch, 148 feet.	1,275	1,107	308	....	....	do	900.00	2,000.00	do	†15
276	John Joss	do	A-10	1898	Bored, 8-inch	1,185	1,044	205	21	....	do	....	....	Domestic; irrigation.	†15

277	Seth Richards Orange Grove Co.	Sec. 5, T. 1 S., R. 8 W.	A-10	1899	Bored, 10-inch	1,200	1,072?	293			Compressed air.	(*b) 12,400.00		Irrigation	
278	do	do	A-10	1899	do	1,190	1,068?	301			do				
279	do	do	A-10	1900	do	1,180	1,064?	322			do				
280	Kingsley Tract Water Co.	San Jose	A-12	1889	Bored, 6-inch	1,185	1,122	265	16		Gas	1,000.00	1,500.00	do	†30
282	O. W. Lorbeer	do	A-14	1902	Bored, 10-inch	860	775?	393			Steam	700.00		Laundry	
283	C. Seaver	do	A-13	1902	Bored, 7-inch	873	777	151			Wind	250.00	90.00	Domestic	1
284	Dr. A. R. Reed	do	A-12	1900	Bored, 9½-inch	1,010	952	200			do			do	
288	M. A. Williams	do	A-12	1896	Dug, 40 feet; bored, 7-inch, 120 feet.	955	923	160			Wind			do	
289	Irrigation Co. of Pomona.	do	A-12	1887	Dug, 4 by 6 foot, 50 feet; bored, 7-inch, 297 feet.	950	915	347			Electric motor	900.00	1,200.00	Irrigation	†60
290	Palomares Irrigation Co.	do	A-12	1886?	Bored, 7-inch	975	938	500			Wind	700.00		Domestic	
291	do	do	A-12	1886?	Dug, 50 feet; bored, 7-inch, 155 feet (2 wells).	995	948	205			Electric motor	400.00	2,450.00	Irrigation	†55
291a	do	do	A-12	1899	Bored, 10-inch	995	948	200			do				
292	Consolidated Water Co.	do	A-12	1904	Bored, 14-inch	985	935	223			do	*3,000.00		do	†60
293	do	do	A-12	1898	Bored, 10-inch	1,010	945	225			do	*3,000.00		Domestic	†30
294	Major Thomas	do	A-12	1892	Bored, 7-inch	1,020	960	200	21		Compressed air.		3,000.00	Irrigation	†25
295	Consolidated Water Co.	do	A-12	1898	Bored, 10-inch	1,005	948	57			Electric motor	*3,000.00		Domestic	†27
295a	do	do	A-12	1897	Bored, 9-inch	1,005	952	223			do				
297	Chino Land and Water Co.	do		1889	Bored, 12-inch	990	950?	535			do	2,000.00?		Domestic; irrigation.	†60
298	Mr. Smith	do			Bored, 9-inch (3 wells).	975	925	229-321			Wind			Domestic	
299	Cathcart estate	do	A-12	1886?	Bored, 12-inch (5 wells).	980	912	300-600			Not raised			Not used	
300	J. W. Romick	do	B-11			1,125	969	200?			Wind			Irrigation	
301	Del Monte Irrigation Co.	Sec. 9, T. 1 S., R. 8 W.	B-11		Bored, 14-inch	1,180	1,090	200†			Not raised			Not used	

---

a Included in Nos. 277-279.

b Including No. 273.

Wells in the foothill belt of southern California—Continued.

POMONA QUADRANGLE.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
1	Currier Tract Water Co.	San Jose	M-13	1900	Bored, 10-inch	855	759	356			Electric motor	$1,200.00	$2,300.00	Irrigation	†70
2	M. L. Garcia	do	M-13	1902	Bored, 7-inch	850	780	100	22		Wind			Domestic	
3	L. R. Phillips	do	L-13	1899	do	800	754	56	22		do			do	
4	L. Monro	do	L-13		do	775	741	103			Not raised			Not used	
5	Mrs. S. L. Fryer	do	K-14		do	735	712	50			Wind			Domestic	
6	Fryer ranch	do	L-14	1900	Bored, 10-inch	738	710	190			Gas			do	
7	Earnest Whipp	do	K-14	1886	Bored, 7-inch	730	704	40	28		do			do	
8	J. M. Fryer	do	K-14	1895	do	720	695	44	25		Wind			do	
9	S. E. Hicks	do	J, K-14	1900	do	745	716	48	35		do			do	
10	J. M. Fryer	do	K-14		Dug, 3 by 3 foot.	745	715	34			Hand			Domestic; stock	
11	Los Angeles County	do	K-14		Bored, 7-inch	780	748	55			Wind			Roads	
12	B. Linnastruth	do	N-13	1900	do	850	772	83	23		do			Domestic	
13	do	do	N-13	1897	do	862	792	75	16		do			do	
14	F. G. Herman	Sec. 30, T. 1 S., R. 8 W.	M, N-13		Bored, 8-inch	850	769	90	21		do			do	
15	Mrs. M. C. Blevett	San Jose	M-13		Bored, 7-inch	840	756	95			do			do	
16	A. M. Way	Sec. 34, T. 1 S., R. 9 W.	K-14	1900	do	695	673	61	24		do	70.00		do	
17	Stanley Bates	do	K-15		Dug, 4 by 6 foot, 11 feet; bored, 7-inch, 69 feet.	678	669	80	25		do			do	
18	Lynch ranch	do	K-15	1898	Bored	670	661	150	24		do			do	
20	D. H. Collins	do	K-15		Dug, 8-foot diameter.	657	656	3	25		do			do	
21	M. T. Scanlon	do	K-15	1901	Dug, 2 foot diameter.	662	659	12	170		Hand			Stock	
22	Antone Rayes	Sec. 4, T. 2 S., R. 9 W.	J-14		Bored, 7-inch	650	639	70	23		Wind			Domestic	
23	R. T. Currier	Sec. 9, T. 2 S., R. 9 W.	J-16, 17		Bored, 8-inch	600	583	86	32		do			do	
24	K. H. Dorsey	San Jose	K-14	1898	Bored, 7-inch	705	682	81			Steam	*1,250.00		Irrigation	50
25	do	do	K-14	1898	Bored, 10-inch	705	682	65			do				
28	Sam Lee Co	do	L-14		do	755	732	149			Gas			do	†40
29	do	do	L-14		do	755	732	149			Flows 23 feet below surface.				

30	D. D. Ross	do	M-14	1880	Bored, 6-inch	840	771	75	25		Wind			Domestic	
31	Robert Allen	do	M-14	1900	Bored, 7-inch	830	780	90	23		do			do	
32	Pomona Brick Co.	do	M-14		do	815	771	80			do			do	
33	Mr. Barnhardt	do	N-14		do	810	769	57	24		do			do	
34	Miss Sarah Dundas	do	N-15		Dug, 6 by 6 foot	800	774	40	29		do			do	
35	D. Hawkins	do	N-14	1885	Bored, 7-inch	840	775	96			do			Irrigation	
36	James Gallaway	do	N-15	1902	do	802	770	70	28		do	115.00	210.00	Domestic; irrigation.	
37	F. C. Westphal	do	N-15	1900	Dug, 4 by 4 foot	790	769	26	22		do			Domestic	
38	Mrs. L. R. Matthews	do	N-15	1899	Bored, 10-inch	800	762	250			Gas	450.00	1,800.00	Irrigation	†80
39	Hill & Wickson	do	N-14	1899	do	815	757	245			do	425.00		do	†75
40	P. R. Perris	do	N-15	1902	Dug, 3 by 3 foot	790	766	25	30		Hand			Domestic	
41	W. C. McGuire	do	N-14	1897	Bored, 8-inch	825	772	110	23		Wind			do	
42	Kerckhoff - Cuzner M. & L. Co.	do	N-13	1885	do	860	783	166			Not raised			Not used	
43	D. R. Kelsey	do	N-13	1902	Bored, 10-inch	880	800	161			Gas	325.00	1,650.00	Irrigation	†25
44	S. J. Bromley	do	N-12	1895	do	935	909	100	18		Wind			Domestic	
45	R. Vejar	do	N-11, 12	1886	Bored, 7-inch	1,046	972	260	16		do	800.00		do	
46	Frank Vejar	do	N-11	1897	do	1,045	968	115	16		do			do	
47	P. T. Yorba	do	M, N-11	1900	do	1,045	964	120	24		do			do	
48	James Fulton	do	N-11	1898	Dug, 4 by 4 foot, 95 feet; bored, 12-inch, 205 feet.	1,070	977	300			Gas			Domestic; irrigation.	†30
49	J. Steves	do	N-11	1895	Bored 7-inch	1,065	985	128	70		do	250.00	450.00	do	†10
50	Lordsburg Water Co.	do	N-11	1899	Dug, 5 by 5 foot, 120 feet; bored, 10-inch, 180 feet.	1,100	981	300			do	800.00	2,200.00	Irrigation	†33
51	William Bosbyshell	do	N-11	1900	Bored, 10-inch	1,050	965	340			do		1,475.00	Domestic; irrigation.	†50
54	B. F. Whipp	do	N-13	1897	Bored, 7-inch	900	840	61	20		Wind			Domestic	
55	Orange Grove Avenue Water Association.	do	N-13	1900	Dug, 5 by 7 foot, 62 feet; bored, 10-inch, 278 feet.	920	904	340	14		Electric motor	1,700.00	1,600.00	Irrigation	†65
56	Mel Campbell	do	N-13	1897	Bored 7-inch	920	908	250	16		Gas	900.00	1,350.00	Domestic; irrigation.	†40
57	do	do	N-13	1896	do	920	908	180			do			Irrigation	
59	Mrs. L. T. Alkire	do	N-13		do	900	862	60			Wind			Domestic	
60	Frank Vejar	do	M-12	1880	do	990	972	48	24		do			Stock	
61	Palomares ranch	do	M-12		Dug, 4 by 4 foot	995	978	20	32		Hand			Domestic	
62	Keiser Bros	do	M-11	1899	Bored, 10-inch	1,030	960	360			Gas			Irrigation	†50
63	Lordsburg Water Co.	do	M-11	1900	Dug, 4 by 5 foot; bored, 10-inch.	1,065	982	202			do	400.00	1,800.00	Domestic; irrigation.	†25
64	S. L. Gross	do	N-11	1902	Bored, 12-inch	1,090	990?	100?			Electric motor		*4,000.00	do	
65	do	do	N-11	1902	Bored, 14-inch	1,090	990?	100?			do				†50
66	H. J. Nichols	do	N-11		Bored, 7-inch	1,115	976	162	18		Wind			Domestic	
67	F. H. Massey	do	N-11	1898	Bored, 10-inch	1,165	977	200+			Not raised			Not used	
69	Mesa Water Co.	Sec. 5, T. 1 S., R. 8 W.	N-10	1903	Dug, 4 by 6 foot, 140 feet; bored, 12-inch, 180 feet.	1,230	1,129	320			Electric motor				†30

Wells in the foothill belt of southern California—Continued.

POMONA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery	Use of water.	Quantity of water (miner's inches).
71	R. E. Winter	Sec. 5, T. 1 S., R. 8 W.	N-9	1901	Bored, 12-inch	1,240	1,110	300			Gas			Domestic; irrigation.	†15
72	R. A. Wallace	Sec. 6, T. 1 S., R. 8 W.	N-10		Bored, 7-inch	1,152	997	165			do			Domestic	5
73	Duarte Mutual Irrigation and Canal Co.	Azuza Duarte	C-8	1901	Dug, 9 by 6 foot.	598	553	218			Steam	*$20,000.00		Domestic; irrigation.	64
74	J. H. Maddock	do	C, D-7	1899	Dug, 2½ by 3½ foot.	695	582	120	28		Gas	*2,000.00		do	†15
75	Duarte Mutual Irrigation and Canal Co.	do	D-7	1902	Dug, 6 by 6 foot.	690	612	130			Not raised			Not used	
76	A. C. Thompson	do	D-8	1900	Dug, 6 by 8 foot.	650	614	80			Steam	*7,000.00		Irrigation	†100
77	D. H. Thrasher	do	C-8	1898	Dug, 4 by 6 foot, 235 feet; bored 12-inch, 26 feet.	550	315	261			Not raised	1,200.00		Not used	
78	West Duarte Development Co.	do	B-7	1903	Dug, 4 by 6 foot, 118 feet; bored, 8-inch, 92 feet.	620	566	210			Gas			Domestic; irrigation.	†15
79	Duarte Mutual Irrigation and Canal Co.	do	B-8		Bored, 10-inch	610	Dry.	200						No water	
80	E. D. Northup	do	B-8, 9	1895	do	475	306	222	26		Wind	1,400.00		Domestic	
81	W. S. Newhall	do	D-7	1900	Dug, 4 by 5 foot.	680	610	100			Steam			Irrigation	†25
82	Orange Avenue Land and Water Co.	La Puente	D-12	1903	Bored, 12-inch	420	293	262			do	1,075.00	$3,400.00	do	
83	Irwindale Land and Water Co.	do	D-12	1899	Dug, 4 by 6 foot, 130 feet; bored 12-inch, 72 feet.	428	294	202	25		do	*5,000.00		do	†65
84	J. F. Irwin	Sec. 16, T. 1 S., R. 10 W.	D-11		Dug, 120 feet; bored, 10-inch, 60 feet.	424	294	180			Gas			do	†35
85	D. L. Allen	Sec. 17, T. 1 S., R. 10 W.	C-11		Bored, 7-inch	390	287	115	28		Wind				

86	Vineland irrigation district plant.	Sec. 9, T. 1 S., R. 10 W.	C-11	1898	Dug, 104 feet; bored, 12-inch, reduced to 10-inch, 370 feet.	400	294	474			Steam	3,000.00		Domestic; irrigation.	†100
87	Vineland school district.	Sec. 18, T. 1 S., R. 10 W.	C-11		Bored, 7-inch	382	288	140	27		Wind			Domestic	
88	C. N. Buck	do.	B-11		do.	372	285	100	28		do.			do.	
89	Washington Bunch	Sec. 7, T. 1 S., R. 10 W.	B-11	1895	Dug, 3 by 3 foot.	380	289	100			Not raised			Not used	
90	Baker ranch	Sec. 18, T. 1 S., R. 10 W.	B-11		Bored, 7-inch	370	284	80			Wind			Domestic	
91	G. Nebbir	Sec. 12, T. 1 S., R. 11 W.	B-11		do.	352	282	75	28		do.			do.	
92	Cypress Avenue Water Co.	La Puente	F-11	1903	Dug, 4 by 6 foot, 170 feet; bored, 12-inch, 130 feet.	466	296	300			Steam	935.00?		Irrigation	
93	P. C. Basher	do.	F-12	1900	Dug and bored, 10-inch.	485	315	304	29		Gas	400.00	900.00	do.	†15
94	William Overholtzer	do.	E-12	1900	Bored, 10-inch	465	300	300	30		do.	800.00	2,175.00	Domestic; irrigation.	23
95	E. C. Mullendor	do.	E-12	1903	Dug, 4 by 6 foot.	430	304	128			Installing plant.				
96	G. F. Chamberlain	do.	E-12, 13.	1900	Dug, 3 by 3 foot.	422	306	118	22		Wind			Domestic	
97	Griffith Bros	do.	E-14	1892	Bored, 7-inch	422	294	130	40		do.			do.	
98	Edward Fickewirth	do.	C-12		Bored, 10-inch	352	307	300?	26		do.			do.	
99	do.	do.	D-15	1900	Bored, 12-inch	362	312	850							
100	do.	do.	D-15	1900	do.	362	302	287			Not raised			Not used	
101	do.	do.	D-15	1900	do.	362	302	307			do.			do.	
102	E. J. Baldwin	do.	A-15		Driven, 2-inch	278	263	24	31		Hand			Domestic	
103	Los Angeles County	do.	A-14		Bored, 7-inch	275	263	60	26		Wind			Roads	
104	C. N. Bassett	do.	A-14	1899	Bored, 12-inch	315	289	125			Steam	2,500.00	2,400.00	Irrigation	135
105	E. M. Haddock	do.	A-14	1900	Bored, 9½-inch	305	275	125	27		do.			do.	†90
106	E. J. Baldwin	do.	B-14		Bored, 7-inch	335	292	58	26		Wind			Domestic	
107	Los Angeles County	do.	C-16		do.	320	302	58	53		do.			Roads	
108	do.	do.	B-15		do.	295	280	65	38		do.			do.	
109	E. J. Baldwin	do.	B-16		Bored, 9-inch	295	286	22			Not raised			Not used	
110	L. F. Lewis	do.	B, C-16.		Bored, 10-inch	312	288	300			do.			do.	
111	J. W. Hudson	do.	C-17	1880	Bored, 7-inch	330	305	39	41		Wind			Domestic	
112	Joseph Ferara	do.	C-17		Dug, 5 feet diameter.	342	320	25	75		do.			do.	
113	Rowland ranch	do.	D-17		Bored, 7-inch	360	326	60	47		do.			do.	
114	San Pedro, Los Angeles and Salt Lake R. R.	do.	D-17	1903	Bored, 14-inch	380	347	300	74		Gas			Engines	
115	Rowland school district.	do.	D-17		Dug, 4 by 4 foot.	350	332	22	71		Hand			Domestic	
116	L. Didier	do.	E-17	1893	Dug, 30 feet; bored, 7-inch, 70 feet.	370	347	100	107						
117	H. Heinze	do.	C-16	1896	Bored, 7-inch	323	297	127	59		Wind			Domestic	
118	E. Rambaud	do.	C-16	1900	Dug, 4 by 4 foot.	340	310	42	78		do.			do.	
119	George Cross	do.	C-16		Bored, 7-inch	342	311	93	57		do.			do.	

Wells in the foothill belt of southern California—Continued.

POMONA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
120	George Cross	La Puente	D-17	1902	Bored, 9½-inch	340	328	148	70		Not raised	$350.00		Not used	
121	William Rowland	do	D-17	1901	Bored, 9⅝-inch	355	331	165			Electric motor	272.50?	$3,500.00	Irrigation	†104
122	do	do	D-17	1901	do	355	331	165			do	272.50		do	
123	do	do	D-17	1901	do	355	331	165			do	272.50		do	
124	do	do	D-17	1901	do	355	331	165			do	272.50		do	
125	do	do	D-17	1901	do	356	320	500			do			Domestic; irrigation.	†15
126	H. L. Armstrong	do	C-17	1902	Bored, 8-inch	320	315	120	58		Gas		1,200.00		
127	do	do	C-17	1902	do	320	315	290			do			Irrigation	†80
128	do	do	C-17	1902	do	320	315	160			do				
129	B. F. Rowland	do	E-17		Bored, 7-inch	370	348	28			Wind			Domestic	
131	Rowland estate	do	D-15		do	345	307	73	31		Hand			do	
132	E. J. Baldwin	do	C-14		do	340	295	80			Wind			do	
133	Robert Rowland	do	F-17		Dug, 5-foot diameter.	390	365	28			do			do	
134	A. H. Yorba	do	F-17	1893	Bored, 7-inch	430	383	84	46		do			do	
135	B. Yorba	do	F-17		do	395	367	50	60		do			do	
136	J. P. Edwards	do	D-17	1901	do	365	330	42	49		do			do	
137	M. Vasquez	do	D-16	1902	Dug, 4 by 4 foot	346	324	30	56		Hand			do	
138	Jose Cota	do	D-16	1903	do	338	324	17	61		do			Domestic; irrigation.	
139	William Aschenbrenner.	do	F-12, 13	1900	Bored, 10-inch	475	325	300			Not raised			Not used	
140	W. G. Kerchkoff	do	G-13	1900	do	545	385	400			Electric motor	*3,000.00		Irrigation	†15
141	G. O. Shouse	do	H-12	1903	Bored, 12-inch	660	553	400	86		Wind			Domestic	
142	do	do	H-12	1900	do	550	550	90			Not raised			Not used	
143	C. H. Cannon	San Jose	J, K-11		Bored, 10-inch	850	Dry.	180						No water	
144	William Ferry	do	J-11	1900	do	855	657	222			Not raised	723.00		Not used	
145	Macneil ranch	Azusa Dalton	G-9		Bored, 12-inch	602	326	600?			do			do	
146	L. G. Parker	Sec. 1, T. 1 S., R. 10 W.	G-10		do	615	344	294			do			do	
147	A. Jackson	San Jose Addition.	H-10	1900	Dug, 3 by 6 foot	745	646	110	65		Gas			Irrigation	†10
148	Hauser Bros. Co.	do	H-10	1900	do	700	Dry.	224						No water	
149	Sidney Deacon	do	J-11		Bored, 12-inch	825	604	160			Steam			Not used	
150	do	do	J-11		do	825	695	155			Not raised			do	

151	H. Rees	San Jose	J-11	1895	Bored, 7-inch	830	Dry.	162	....	....				No water	......
152	A. R. Evans	La Puente	F-13	1899	Bored, 10-inch	485	330	400	....	....	Compressed air	1,300.00	2,700.00	Irrigation	†20
153	Mr. Davison	Sec. 31, T. 1 N., R. 9 W.	H-9	1900	Dug, 4 by 6 foot	638	652	70	27	....	Not raised			Not used	......
154	B. F. Taylor	San Jose Addition.	H-10	1899	Dug, 5-foot diameter.	720	653	86	23	....	do			do	......
155	West Middleton	do	I-10		Dug, 3 by 6 foot	810	Dry.	116	....	....				No water	......
156	William Bowring	do	I-10	1900	Dug, 4 by 4 foot	810	682	158	35	....	Not raised	1,000.00		Not used	......
158	J. W. Cook	Sec. 20, T. 1 N., R. 9 W.	I-7	1897	Dug, 4 by 6 foot	1,050	1,036	70	49	....	do			do	......
159	John Engelehardt	do	I-7	1899	do	1,080	Dry.	200	....	....		2,000.00		No water	......
160	I. R. Miller	do	I-7	1897	do	1,070	1,058	64	76	....	Not raised			Not used	......
161	J. F. Shank	Sec. 31, T. 1 N., R. 9 W.	H-9	1899	Bored, 10-inch	700	Dry.	190	....	....				No water	......
162	G. S. Thomas	do	H-9	1898	do	738	628	185	34	....	Gas			Domestic	7
163	W. H. Hall	do	H-9	1899	Dug, 3 by 6 foot	730	624	112	32	....	do			Irrigation	......
164	A. B. Rodgers	do	H-9	1899	Dug, 4 by 6 foot	725	620	151	....	....	Not raised	1,000.00		Not used	......
165	J. H. Hommell	do	H-9	1900	Bored, 10-inch	700	580	190	....	....	Gas	300.00	950.00	do	7
166	Jacob Boerlin	do	H-9	1903	Dug, 4 by 4 foot	740	713	33	48	....	Hand				......
181	Pomona Land and Water Co.	San Jose	N-12	1894	Bored, 7-inch	1,000	945	325	....	....	Electric motor	1,200.00	2,200.00	Irrigation	†60
182	Irrigation Co. of Pomona.	do	N-12	1888	Bored, 9½-inch and 8-inch.	960	....	950	....	....	Compressed air	6,000.00	1,500.00	do	†60
183	do	do	N-12	1887	Bored, 7-inch	955	....	440	....	....	do	900.00		do	†15
185	Mr. Strause	Sec. 8, T. 2 S., R. 9 W.	I-17	1896	Dug, 3 by 3 foot	555	537	20	55	....	Hand			Domestic	......
186	Paton & Co.	Sec. 17, T. 2 S., R. 9 W.	I-17	1903	Bored, 10-inch	570	532	60	31	....	Gas	300.00	1,500.00	Irrigation	†77
187	McClintock, Lee & St. Clair.	La Puente	I-17	1902	do	550	518	100	....	....	do	250.00	1,360.00	do	†62
188	Mrs. E. M. Dailey	do	I-17	1897	Bored, 8-inch	540	517	55	....	....	do			do	†60
189	Mr. Swan	do	I-17	1902	Bored, 7-inch	550	517	55	....	....	Wind			Domestic	......
190	G. W. Bowman	do	H-17	1903	Dug, 4 by 6 foot	535	514	38	46	....	Gas	350.00	1,100.00	Irrigation	†80
191	L. Snodgrass	do	H-17	1894	Bored, 7-inch	510	487	40	56	....	Wind			Domestic	......
192	S. M. Bowers	do	H-16	1903	Dug, 6 by 8 foot	555	527	40	....	....	Gas		600.00	Irrigation	†12
193	B. F. Bowers	do	H-16	1903	do	560	530	36	55	....	do			do	5
194	William Rowland	do	H-17	1890	Dug, 3 by 3 foot	540	502	45	52	....	Wind			Domestic	......
195	W. H. Swan	do	H-17	1896	Dug, 3½ by 3½ foot.	530	505	30	....	....	do			do	......
196	G. W. Bowman	do	H-17	1891	Bored, 4-inch	530	502	120	52	....	do			do	......
197	F. M. Howell	do	H-17	1902	Dug, 8 by 8 foot	515	495	40	....	....	Gas			Irrigation	†25
198	Joseph Monroy	do	I-16	1896	Dug, 3 by 3 foot	540	528	14	55	....	Wind			Domestic	......
199	James Huff	San Jose	M-11	1899	Bored, 10-inch	1,010	966	280	21	....	do	600.00	75.00	do	......
200	Covina Irrigating Co	do	M-11	1898	Bored, 10-inch (5 wells).	995?	950?	240-400	....	....	Compressed air	7,000.00	7,000.00	Irrigation	†125
201	do	do	M-11	1899	do	995?	950?	240-300	....	....	do				
202	J. S. Soto	do	M-11	1884	Bored, 7-inch	1,020	972	50	17	....	Wind			Domestic	......
203	A. A. Macias	do	M-11	1899	Dug, 3½ by 3½ foot.	1,015	973	43	....	....	do			do	......
204	Mrs. Dolores de Carrión.	do	L-11	1898	Dug, 5 by 5 foot, 40 feet; bored, 10-inch, 40 feet	975	951	80	....	....	Gas	400.00	700.00	Domestic; stock	†10

Wells in the foothill belt of southern California—Continued.

POMONA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
205	Margaret Flemming.	San Jose	M-11	1897	Bored, 7-inch	1,042	1,002	275	....	....	Compressed air.	$600.00	$3,500.00	Irrigation	† 25
206	H. C. Fisher	do	M-11	1894	do	1,049	1,004	375	....	....	Gas	700.00	450.00	do	† 7
207	Stratton & Hayes	Sec. 1, T. 1 S., R. 9 W.	M-10	1891	do	1,135	1,037	170	....	....	do	275.00	500.00	do	† 10
208	A. Baker & Son	Sec. 36, T. 1 N., R. 9 W.	M-9	1902	Bored, 12-inch	1,215	1,031	347	....	....	do	1,259.00	1,250.00	Domestic	8
209	do	Sec. 1 T. 1 S., R. 9 W.	M-9	1902	do	1,175	995	450	....	....	do	1,500.00	5,200.00	Irrigation	† 40
210	N. L. Sparks	Sec. 36, T. 1 N., R. 9 W.	M-9	1901	Dug, 157 feet; bored, 12-inch, 167 feet.	1,185	1,001	324	....	....	do	1,100.00	4,000.00	do	† 40
211	Williams Bros	San Jose	L-9	1900	Dug, 136 feet; bored, 10-inch, 139 feet.	1,090	920	275	....	....	do	....	....	do	† 30
212	A. Swerdfeger	do	L-10	1902	Bored, 12-inch	1,080	915	300	....	....	do	....	....	do	† 35
213	W. T. Michael	do	L-9	1897	do	1,120	1,035	200	31	....	do	750.00	3,000.00	do	† 25
214	Partin & Allman	do	M-9, 10	1900	do	1,130	980	350	....	....	do	225.00	2,250.00	do	† 30
215	Michel, Bixby, Kroeger & Co.	Sec. 1, T. 1 S., R. 9 W.	M-9	1902	do	1,140	980	339	....	....	do	....	1,750.00	do	† 35
216	James A. Johnstone.	San Jose	M-10	1902	Bored, 14-inch	1,095	970	333	....	....	do	....	4,000.00	do	† 35
217	L. S. Thacker	do	M-10	1893	Bored, 7-inch	1,085	970	152	....	....	Wind	225.00	125.00	Domestic	....
218	F. H. Paine	Sec. 36, T. 1 N., R. 9 W.	M-8	1902	Bored, 12-inch	1,305	1,238	148	....	....	Gas	600.00	800.00	Irrigation	† 8
219	E. W. Hart	San Jose	L, M-10	1901	do	1,095	972	300	17	....	do	1,000.00	1,200.00	do	† 20
220	W. S. Carson	do	L-10	1896	Bored, 7-inch	1,070	972	124	20	....	Wind	175.00	60.00	Domestic	....
221	Laverne Irrigating Co.	do	M-10	1903	Bored, 12-inch	1,095	971	230	....	....	Gas	840.00	....	Irrigation	† 35
222	L. C. Meredith	do	L-10	1895	do	1,060	967	265	....	....	do	600.00	1,700.00	do	† 30
223	R. C. Callander	do	L-10	1900	Bored, 10-inch	1,065	920	233	25	....	do	200.00	950.00	do	† 20
224	Frostless Belt Water Co.	do	L-10	1902	do	1,042	948	254	23	....	do	1,000.00	1,800.00	do	† 30
225	George E. Coleman and Laverne Irrigating Co.	do	L-10	1900	do	1,050	985	270	....	....	do	....	1,200.00	do	† 52

226	W. G. Doughty	San Jose Addition.	L-9	1900	do	1,055	920	246			Steam	1,000.00	2,500.00	do	†52
227	L. S. Thacker	do	L-9	1899	Bored, 12-inch	1,050	920	245			Gas	700.00	2,200.00	do	†20
228	San Dimas Irrigation Co.	do	L-9	1900	do	1,055	913	264	24		do		3,500.00	do	†40
229	Johnston & Rutherford.	San Jose	L-10	1901	do	1,065	921	216			do	1,000.00	3,500.00	do	†30
230	Covina Irrigating Co.	San Jose Addition.	L-9	1904	do	1,045	915	270			do	500.00	1,500.00	do	
231	Glendora and Azusa Water Co.	Sec. 35, T. 1 N., R. 9 W.	L-9	1900	do	1,065	912	376			Electric motor			do	†45
231a	do	do	L-9	1901	do	1,065	912	530			do			do	†110
232	Western Water and Power Co.	do	L-9	1900	do	1,070	915	514	24		Steam	9,387.44	13,995.32	do	†125
233	do	do	L-9	1901	do	1,075	915	546	24		do			Domestic; irrigation.	
234	Citrus Belt Water Co.	do	L-9		Bored	1,070	913					*4,000.00			
235	San Dimas Irrigation Co.	San Jose	L-10	1898	do	1,005	954	220			Steam			Irrigation	†45
236	New Deal Land and Water Co.	do	L-10	1898	Bored, 10-inch	1,020	953	170			Gas	305.00	564.00	do	†18
237	San Dimas Irrigation Co.	do	L-10	1902	Bored	1,025	955	300			do	700.00	2,500.00	do	†30
238	David Teague	do	L-11	1898	Bored, 10-inch	980	850	260			do			do	†20
239	J. C. Marquart	Sec. 32, T. 1 N., R. 9 W.	I-9		Dug, 4 by 4 foot	830	740				Not raised			Not used	
240	S. R. Deacon	Sec. 33, T. 1 N., R. 9 W.	J-9	1903	Bored, 7-inch	840	770	102	30		do			do	
241	Columbia Land and Water Co.	San Jose Addition.	K-9, 10	1897	Bored, 12-inch (2 wells).	940	880	180	21		Gas	1,200.00	2,500.00	Irrigation	†50
242	Covina Irrigating Co.	do	K-10	1889	Bored, 12-inch	930	880	150			do	2,000.00	3,000.00	do	†42
244	James Walker	do	K-10	1902	do	1,005	905	200			Steam			do	†50
245	Artesian Belt Water Co.	do	L-10	1898	do	1,010	909	386			do			do	†35
245a	do	do	L-10	1899	do	1,010	909	210			do			do	†35
246	E. Firth	do	K-9								Gas			do	†20
247	Valentine Peyton	San Jose	N-10	1905	Dug, 166 feet; bored, 12-inch, 436 feet.	1,145	997?	636			Steam	*14,000.00		do	
248	Live Oak Water Co.	Sec. 6, T. 1 S., R. 8 W.	N-9		Bored, 12-inch	1,275	1,123	383			Electric motor	*4,000.00		do	†30
249	Laverne Land and Water Co.	Sec. 5, T. 1 S., R. 8 W.	N-10	1900	Bored, 12-inch (2 wells).	1,235	1,075	300?			Gas	1,800.00	5,000.00	do	†55
250	Charles Alley	San Jose	M-10		Bored, 10-inch	1,120	975	175			Wind			Stock	
251	Azusa Irrigating Co.	San Jose Addition.	K-10	1899	Dug, 4 by 10 foot, 104 feet; bored, 12-inch, 200 feet.	1,000	903	304?			Not raised			Not used	
252	George Smith	La Puente	G-12		Bored, 7-inch	550	333	220			do			do	
253	W. A. Sproul	Azusa Dalton	F-8		Dug, 3 by 3 foot	645	557	88			Gas	*2,000.00		Irrigation	†15

Wells in the foothill belt of southern California—Continued.

POMONA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery	Use of water.	Quantity of water (miner's inches).
254	Azusa Agricultural Water Co.	Azusa Dalton	E-8		Dug, 90 feet; bored, 15-inch, 120 feet.	690	600	210			Not installed				
255	do	Sec. 23, T. 1 N. R. 10 W.	F-7		Dug, 6 by 8 foot.	700	630	100			Electric motor		*$5,000.00	Irrigation	†50
256	William Rowland	La Puente	D-17	1902	Bored, 10-inch	350	280	90			Wind			Domestic; stock	
257	F. Bowers	do	H, I-17	1900	Bored, 7-inch	525	502	40			do			Domestic	
258	S. E. Hicks	San Jose	K-14		do	700	664	78			do			do	
259	Los Angeles County	do	K-14		do	705	667	55			do			Roads	
260	Irrigation Co. of Pomona.	do	N-12		Bored, 9½-inch	950	912	51			Not raised			Not used	
261	Mrs. M. Myers	do	N-12		do	950	913	97			Wind			Domestic	
262	A. T. Currier	Los Nogales	J-15	1898-1902	Bored, 9½-inch (6 wells).	625	625	80-115			Artesian			Irrigation	86
263	San Pedro, Los Angeles and Salt Lake R. R.	do	K-15		Bored, 7-inch	655	655	32			do			Not used	1

PASADENA QUADRANGLE.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery	Use of water.	Quantity of water (miner's inches).
1	Mrs. Titus	Santa Anita	I-8	1892	Bored	690	674?	558			Wind	$4,000.00		Domestic; irrigation.	
2	G. Hutchinson	do	I-8	1890	Bored, 8-inch	713	651	230			do			Domestic	
3	J. P. Butler	do	I-8	1894	Bored, 7-inch	720	630	127			Gas	175.00	$480.00	Domestic; irrigation.	3
4	J. T. Butler	do	I-8	1902	do	713	658	150			do	375.00	500.00	do	5
5	F. E. Chapman	do	H, I-8	1888	do	725	655	104			do	200.00	50.00	do	3
6	Mrs. Black	do	H-8			712	654	100?							
7	R. H. Schoemaker	do	H-8	1900	Bored, 10-inch	722	652	130?			Gas	200.00	100.00	Domestic; irrigation.	
8	J. B. Bonnalie	do	H-8	1897	Bored, 7-inch	723	649	102			do	110.00	350.00	do	
9	James MacAdam	do	H-8	1893	do	740	651	150			do	400.00	1,000.00	do	3
10	Mr. Merwin	do	H-8			735	657	95							

11	Mrs. L. C. Scoville	do	H-8	1896	Bored, 7-inch	741	669	175						Domestic; irrigation.	
12	I. McCollum	San Pasqual	H-8			785	663	151			Wind			do	
14	G. W. Clark	Santa Anita	H-8	1897	Bored, 7-inch	776	651	151			Wind; gas			do	2
15	H. L. Moses	San Pasqual	H-8	1895	do	790	664	200			Gas	350.00	220.00	do	†2
16	H. C. Rice	do	H-8	1902	do	798	658	196			do	260.00	435.00	do	4
17	S. V. Harkness	do	H-8	1902	Bored, 12-inch	787	670	272			Not raised	265.00		Not used	
21	Mr. Miles	Santa Anita	I-7			817	652	225			Gas		400.00		
22	Andrew Ruedy	do	I-7	1884		813	646	168			Wind		255.00	Domestic	
23	C. A. Hobart	do	J-7	1899	Bored, 7-inch	705	610	129				165.00		Stock	
24	Pasadena Brick Yard.	do	G-9	1901	do	750	694	750			Not raised			Not used	
25	City of Monrovia	do	K-8		Bored, 10-inch	645	628	540			Compressed air		5,000.00	Domestic; irrigation.	†25
26	do	do	K-8	1902		645	633	386			do			do	
27	do	do	K-8			645	633	386			do			do	†115
28	C. F. Lee	San Pasqual	H-7	1902	Bored, 7-inch inside of 10 inches.	796	656				Gas	470.00	1,450.00	do	11
29	Mr. Garvin	do	H-8		Bored, 10-inch	784	657	290			Not raised			Not used	
30	E. A. Bonine	Santa Anita	I-8	1881	Bored, 7-inch	749	664	113			Gas	115.00	750.00	Domestic; irrigation.	2
31	P. S. MacKay	do	I-8	1902	Bored, 8-inch	722	635	250			Compressed air	525.00	1,065.00	Irrigation	†15
32	Mrs. Baker	do	I, J-8	1896	Bored, 7-inch	700	619	86			Wind	100.00	70.00	Domestic; irrigation.	
33	Mrs. Humphrey	do	I, J-8			690	622	90+							
34	Mr. Ackerman	do	I-8		Bored	710	630	149							
35	F. C. Ballinger	do	I-8	1882?		686	645	55			Wind				
37	Titus ranch	do	I-9			635	633	153			Electric motor			Irrigation	
41	I. N. Van Nuys	do	I-9		Bored, 10-inch	633	623	482			Flows into tunnel.			do	15
42	do	do	I-9		Bored, 7-inch	633	623	280			Siphon			do	16
43	do	do	I-9		do	633	623	71			do			do	10
44	do	do	I-9		do	633	623	25			Not raised			Not used	
45	do	do	I-9		do	633	623	25			do			do	
46	do	do	I-9		do	633	623	25			do			do	
47	do	Sec. 35, T. 1 S., R. 12 W.	I-9								Tunnel				6
48	William Blake	San Pasqual	F-8	1900	Dug, 3½ feet diameter.	812	748	65			Wind		55.00		
49	F. W. Richmond	do	F-8	1896	Dug, 30 feet; bored, 30 feet.	790	743	60?			do			Domestic	
50	Charles Wilson	do	F-9	1900	Dug, 3½ feet diameter.	775	745	33			Hand	100.00		do	
51	Pasadena and Pacific power house.	do	F-9		Bored, 10-inch	750	719								
52	Raymond station	do	F-9		Dug, 12 feet diameter.	750	728	24							
53	Euclid Avenue Water Co.	do	F-9	1901	Bored, 12-inch	750	727	126			Electricity			Irrigation	26

Wells in the foothill belt of southern California—Continued.

PASADENA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
54	Oak Knoll ranch	San Pasqual	G-9	1899	Dug, 41 feet; bored, 12-inch, 148 feet.	752	709	189			Electric motor	*$1,500.00		Irrigation	†48
55	do	do	G-9		Dug, 50 feet; bored, 7-inch, 100 feet.	752	709	150			Gas			do	15
56	Hurlbut place	do	F-9		Bored, 7-inch	816	745	1,300						Not used	
57	I. A. & T. T. Cooper.	Sec. 34, T. 1 N., R. 12 W.	H-9	1901	Bored, 12-inch, 600 feet; 10-inch, 200 feet.	600	338	800				3,700.00		do	
58	Garvey Water Co	Sec. 35, T. 1 N., R. 12 W.	H-9		Bored, 10-inch	634	614	360			Gas			Irrigation	†30
59	do	Santa Anita	H-9		Bored, 12-inch	700	620	360			Electric motor			do	
60	do	do	H-9			700	620	350			do			do	
64	do	do	H-9		Bored, 7-inch	660	650	60						Not used	
65	Mr. Baker	San Pasqual	E-9			740	717	32						Domestic	
66	F. J. Culver	do	E-9	1899	Dug, 5-foot diameter.	748	720	59			Electric motor				8
67	do	do	E-9			752	719	50							
68	Mr. Reed	do	F-8		Bored, 12-inch	860	734	200+			Gas			Domestic; irrigation.	†9
70	Mr. Cooper	do	E-7			845	759	90			Wind				
71	Weymouth & MacAdams.	do	E-7	1902	Bored, 12-inch	850	746	457						Not used	
72	Mr. Stone	do	E-5, 6		Dug, 6 by 4 foot.	1,040	954	106							
73	Mr. Lloyd	do	E-6		Dug, 3 by 4 foot.	1,035	952	85			Wind				
74	MacDonald & Staats	do	E-6		do	995	865	134							
75	K. G. Hommel & Co.	do	F-5	1900	Dug, 5 by 4 foot.	1,185	984	210			Gas	500.00	$1,200.00	Not used	
76	Mountain View Cemetery.	do	F-5	1902	Dug, 4-foot diameter.	1,185	940	265			do	1,000.00	1,200.00	Irrigation	†8
78	Rubio Canyon Land and Water Association.	do	G-5	1902	Bored, 12-inch	1,150	965	280			do	850.00	4,300.00	Domestic; irrigation.	23
80	Mr. Meer	do	G-6			1,060	884	300							
81	Fair Oaks ranch	do	H-6			1,090	800	300?							
82	do	Santa Anita	I-6	1902	Bored, 12-inch	1,010	770	330			Gas	825.00	3,000.00	Irrigation	†22

83	Mr. Craig	do	H-7	1899	Bored, 11-inch	855	635	632			Electric motor		950.00	Domestic; irrigation.	20
84	Thomas B. Bishop	Sec. 15, T. 1 S., R. 12 W.	G-12	1901	Bored, 12-inch	465	279	190						Not used	
85	W. N. Murray	do	H-12	1899	Bored, 10-inch	425	290	265			Gas	499.50	1,327.50	Irrigation	†10
86	John Cazauraug	Sec. 21, T. 1 S., R. 12 W.	F-13			440	416				Wind			do	
88	H. E. Farmen	Sec. 22, T. 1 S., R. 12 W.	G-13	1902	Bored, 12-inch	410	298	266			Gas				
89	do	do	G-13		do	408	299	455							
90	do	do	G-13		do	402	296	450							
91	Mr. Howe	Sec. 27, T. 1 S., R. 12 W.	H-13		Bored, 10-inch	383	331	100							
92	P. G. Mason	Sec. 23, T. 1 S., R. 12 W.	I-13	1902	Bored, 5½-inch	350	286	74			Not installed	56.00			
93	Martin Haig and J. & E. Parker.	Potrero Grande	J-13		Bored, 7-inch	267	267	424			Compressed air, artesian.			Irrigation	
94	do	Sec. 24, T. 1 S., R. 12 W.	I-13		do	285	260	686			Compressed air			do	†60
95	do	Potrero Grande	J-13		do	267	262	263						Not used	
96	do	Sec. 26, T. 1 S., R. 12 W.	J-13			400	300	160						Domestic	
97	Garvey ranch	Potrero Grande	J-13	1898	Bored, 12-inch	267	267	775			Compressed air, artesian.	3,000.00		Irrigation	150
98	do	do	J-13	1899	Bored, 10-inch	267	267	425			Artesian	1,050.00		do	
99	do	do	J-13	1895	Bored, 7-inch	267	267	214			do	550.00		do	
100	do	do	J-14	1888	do	265	257	75			Wind				
101	E. J. Baldwin	do	J-14			260	260	100			Artesian, wind			Stock; irrigation.	
102	F. E. Wilson	Sec. 24, T. 1 S., R. 12 W.	I-13	1901	Bored, 6-inch	287	267	36			Wind			Domestic	
103	A. J. B. Immel	do	I-13	1902	Bored, 10-inch	297	270	203			Gas	400.00	400.00	Irrigation	12
104	F. Wyman	do	I-13		Bored, 7-inch	300	269	60			Hand			Domestic	
105	H. McCoy	do	I-13		do	311	274	51			Wind			do	
106	Mrs. C. E. Mitchell	do	I-13		do	312	274				do	225.00		do	
107	John McClain estate	Sec. 14, T. 1 S., R. 12 W.	I-12	1896	do	342	273	130			do			do	
108	John McKay	do	I-12	1896	do	337	273	110			do	130.00	75.00	do	
109	Judge Northrup	Sec. 23, T. 1 S., R. 12 W.	I-12, 13		do	330	273				do				
110	W. W. Gaines	Sec. 24, T. 1 S., R. 12 W.	I-13	1900	do	317	274	100			do			Domestic	
111	John McClure	do	J-13	1890	Dug, 3-foot diameter.	320	282	44							
112	do	do	J-13		do	320	280	51							
113	Isabell McLeod	Sec. 13, T. 1 S., R. 12 W.	I-12	1867	Dug, 4 by 6 foot, 50 feet; bored, 10-inch, 30 feet.	330	285	80						Not used	
114	Pasadena city farm	Sec. 14, T. 1 S., R. 12 W.	H-12		Bored, 7-inch	387	287	150			Wind, horsepower.			Domestic	
115	G. Purcell	Sec. 11, T. 1 S., R. 12 W.	I-11		Dug, 3-foot diameter.	416	378	45			Wind			do	

Wells in the foothill belt of southern California—Continued.

PASADENA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
117	Warde Bros.	Sec. 13, T. 1 S., R. 12 W.	I-12		Bored, 7-inch	328	278	80			Wind				
118	A. E. McClintock	Sec. 19, T. 1 S., R. 11 W.	I-12	1876	do	310	269	52			do		$130.00	Domestic	
119	Harry E. Rose	Sec. 7, T. 1 S., R. 11 W.	J-11	1900	Bored, 12-inch	380	289	350			Steam	$*7,000.00		Irrigation	75
120	do	do	J-11	1900	do	380	289	650							
121	Reed ranch	Sec. 18, T. 1 S., R. 11 W.	I-12		Bored, 7-inch	330	262				Wind			Domestic	
122	J. Rudel winery	Sec. 7, T. 1 S., R. 11 W.	J-11	1890	do	398	300	300			Compressed air	500.00	1,500.00	Domestic; irrigation.	40
123	Margaret Tecklenborg.	Sec. 9, T. 1 S., R. 12 W.	H-11	1901	Bored, 12-inch	468	293	311			Gas	650.00	1,500.00	do	†10
124	A. C. Weeks	Sec. 10, T. 1 S., R. 12 W.	G, H-11		do	480	295	294			do	700.00	1,700.00	do	
125	E. E. McCollough	Sec. 11, T. 1 S., R. 12 W.	H-11	1899	Bored, 10-inch	430	330	451			do	*4,000.00		Irrigation	
126	S. F. Wuest	Sec. 9, T. 1 S., R. 12 W.	G-11	1899	Bored, 9½-inch	565	325	470			do	1,000.00	2,000.00	do	12
127	H. Hellman	Sec. 7, T. 1 S., R. 11 W.	J-11		Bored, 7-inch	402	301	166			Wind			Domestic	
128	J. W. Barton	San Francisquito	K-11		Bored, 10-inch	375	285	105			do			do	
129	Mr. Lukens	do	L-11		Bored, 7-inch	370	283	95							
130	Mr. Olmstead	do	L-11		do	350	284				Wind, gas			Domestic; irrigation.	
131	Mrs. Olmstead	do	L-11			351	283				Wind			do	
132	Mr. Meek	do	L-11		Bored, 7-inch	342	281				Gas				
133	T. S. Stucker	do	L-11	1895	do	326	280	50			Wind	45.00	60.00	Domestic	
134	J. A. Lucas	do	L-11	1893	do	320	281	180			do			Domestic; irrigation.	
135	J. C. Hannan	do	L-11		do	322	282	70			do				
136	E. J. Baldwin	do	L-11		do	306	280	27			Hand			Domestic	
137	C. E. Gidley	do	L-11, 12.	1891	do	314	277	48			Wind			do	
138	J. W. Cushing	do	K-11		do	328	284	60			do			do	
139	J. Murray Craig	do	K-12		do	306	276	80			do			do	
140	John Abell	do	K-12		do	298	278	30			do			do	
141	J. A. Saw	do	L-12		do	282	280	60			do	60.00	170.00	do	

142	J. H. Jones	do	K-12	1890	do	286	273	26						do	
143	F. A. Forst	do	K-12		do	292	274				Wind				
144	Savannah cemetery	Sec. 18, T. 1 S., R. 11 W.	K-12		do	305	267	45			do			Irrigation	
145	Annie P. Adams	San Francisquito	K-12	1897	do	326	284	78			do	130.00		Domestic	
146	C. W. Cook	Sec. 18, T. 1 S, R. 11 W.	K-12		do	340	284	90			do				
147	do	do	K-12		Dug, 60 feet; bored, 10-inch, 26 feet.	345	285	86			Horsepower			Irrigation	
148	Andrew Lassmull	Sec. 19, T. 1 S., R. 11 W.	J-13	1888	Bored, 7-inch	284	260	64			do		40.00		
149	C. E. Negus	Potrero Grande	J-13	1899	Dug, 4 foot diameter.	250	247	6			Hand			Domestic	
150	Mr. Olmstead	do	J-14		Dug, 2 foot diameter.	249	246	6							
151	E. J. Baldwin	do	K-13		Dug, 2½ by 2½ foot.	248	242	10			Hand			Domestic	
152	T. P. Herbert	do	L-13	1901	Driven, 2-inch	255	247	18			do			do	
153	E. J. Baldwin	do	L-13		Bored, 7-inch	260	248	23			Gas			Domestic; irrigation.	
154	L. A. Crawford	Sec. 21, T. 1 S., R. 11 W.	L-13		do	270	256	18			Wind			Domestic	
155	F. Crab	do	L-13		Bored, 10-inch	273	256	130			Gas			Irrigation	
156	W. R. Dodson	do	L-13	1897	Bored, 12-inch	280	263	153			do	200.00	1,000.00	do	
157	Southern Pacific R. R.	San Francisquito	L-12	1870	Bored, 7-inch	285	261	480			Steam			Engines	6
158	G. H. Kallmayer	Sec. 21, T. 1 S., R. 11 W.	L-13	1895	do	280	261	30			Wind			Domestic	
159	Los Angeles County	San Francisquito	L, M-13		do	280	259				do			Stock	
160	Nicholas Smith	do	M-13	1879	do	280	261	40			do				
161	Newman ranch	Sec. 28, T. 1 S., R. 11 W.	M-13		do	270	257	80			do			Domestic	
162	Mountain View school.	Potrero de Felipe Lugo.	M-13		do	280	260	24			do			do	
163	Los Angeles County	San Francisquito	M-13		do	284	261	30			do			Stock	
164	T. D. Andrews	Potrero de Felipe Lugo.	M-13, 14		do	275	257	25			Hand			Domestic	
165	Newman ranch	Sec. 22, T. 1 S., R. 11 W.	L-13		Bored, 10-inch	280	261	140			Gas			Irrigation	
166	Hop Yuck Co	Sec. 28, T. 1 S., R. 11 W.	L-14		Dug, 3 by 3 foot	258	250	9			Hand			Domestic	
167	Com Song Co	Potrero Grande	L-14		do	254	247	8						do	
168	W. L. Hinman	do	L-14	1900	Bored, 7-inch	248	241	35			Wind	40.00		do	
169	Sam Gee Co	do	L-14			245	240	7			Hand			do	
170	J. R. Allen	Potrero de Felipe Lugo.	L-15	1899	Bored, 7-inch	245	238	42			Wind	42.00		do	
171	J. D. Durfee	do	L-15		do	242	236	40			do			do	
172	Charles Flickett	do	M-15		do	249	238	29			do			Domestic; irrigation.	
173	Jackson Frees	do	N-14		do	290	267				do			Domestic	
174	do	do	N-14		Bored, 12-inch	292	266	95			Gas	450.00	2,000.00	Irrigation	
175	A. E. Shugg	do	M-14	1887	Bored 7-inch	280	260	48			Wind			Domestic	

Wells in the foothill belt of southern California—Continued.

PASADENA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
176	William Elliot	Potrero de Felipe Lugo.	N-14		Bored, 7-inch	271	255	25			Wind				
177	W. S. Parker	do	M-15		do	252	242	38			Hand				
178	G. Castino	do	M-15	1900	Bored, 1½-inch	250	238	18			do			Domestic	
179	Lou Gan	Potrero Grande	L-15		Dug, 2 by 2 foot.	223	218	70			do			do	
180	H. C. Yerby	do	K-15	1898	Bored, 7-inch	220	213	100			Wind			do	
181	Puente school	Paso de Bartolo.	K, L-15		do	215	207				Hand			do	
182	S. A. McClean	do	K-16		do	215	204	50			Wind, horse-power.			Domestic; irrigation.	
183	E. J. Baldwin	do	K-16		Dug, 2 by 2 foot.	210	204	7			Hand			Domestic	
184	G. Puima	do	K-16		do	200	194	7			Wind			do	
185	M M. Zunica	do	J-16		Dug, 4 by 4 foot.	210	197	14			Hand			do	
186	Mr. Botha	do	K-16		Dug, 3 by 3 foot.	195	187	10						do	
187	Joe Contraro	do	J-16		do	195	187	9			Hand			do	
188	O. Fizzette	do	J-16		Bored, 4-inch	190	182	45			do			do	
189	W. Hyler	do	J-16		Driven, 2½-inch.	190	180	12			do				
191	Rincon Irrigation Co.	do	L-17	1901	Bored, 10-inch	220	208	165			Gas	$*2,200.00		Irrigation	
192	R. Garvey	Sec. 27, T. 1 S., R. 11 W.	N-14	1902	Bored, 7-inch	290	265	60			Wind	70.00		Domestic	
193	T. J. Wiggins	Sec. 26, T. 1 S., R. 11 W.	N-14		do	280	262	57			Hand			do	
194	do	do	N-14	1898	Bored, 12-inch	270	266	104			Steam	225.00	$1,000.00	Irrigation	100
195	E. J. Baldwin	Sec. 35, T. 1 S., R. 11 W.	N-15			290	258	50			Wind			Domestic	
196	Mr. Harvey	Sec. 3, T. 2 S., R. 11 W.	M-15		Dug, 3 by 3 foot.	300	251	50			Hand			do	
198	John Petriti	Paso de Bartolo.	L-17		Dug, 4 by 4 foot.	220	193				Wind				
199	Joseph Eady	do	K-17		Bored, 4-inch	205	192	86			do			Domestic	
200	Paso de Bartolo Water Co.	do	K-16		Bored, 10-inch (3 wells).	200	200	300			Artesian			Irrigation	
201	do	do	K-16		Bored, 10-inch	200	188	350			Steam		2,500.00	do	
202	Mr. Pellett	do	K-16			200	187	20			Hand			Domestic	
203	Mrs. Phoebe Barnett.	do	K-16		Bored, 7-inch	195	181	33			Wind			do	
204	California Domestic Water Co.	San Francisquito	N-13	1902	Bored, 15-inch, 580 feet; 12-inch, 420 feet.	296	274	1,000			Compressed air.			Irrigation	

205	Thomas McMichael	do	N-13		Bored, 7-inch	292	266	50			Wind			Domestic	
206	E. T. Hargrave	do	N-13		do	296	267	72			do				
207	W. Richards	do	M-13		Bored, 10-inch	286	284	114			Steam			Domestic	
208	A. C. Drake	do	N-13		Bored, 7-inch	290	262	45						Irrigation	
209	do	do	N-13		Bored, 12-inch	308	270	140			Gas			Domestic	
210	A. E. Nelson	do	N-12	1902	do	318	274	127			Hand	200.00		do	
211	B. A. Benjamin	do	N-12		do	318	274	93			Wind, gas			Domestic; irrigation.	
212	John Hayes	Sec. 14, T. 1 S., R. 11 W.	N-12	1901	do	316	273	112			Gas	700.00	2,500.00	Irrigation	
213	do	San Francisquito	N-12	1901	do	315	272	130			do				
214	James Freer	do	M-13	1897	Bored, 7-inch	292	267	46			Wind, horsepower.			Domestic	
215	M. Metcalf	do	M-13	1900	do	290	267	45			Wind			do	
216	J. S. Killian	do	N-12		Bored, 12-inch	325	272	130			Steam			Irrigation	
217	do	do	N-12		do	325	272	100			do			do	
218	do	do	N-12		do	325	272	100			do			do	
219	do	do	N-12		do	325	272	100			do			do	
220	John Hayes	do	N-12		Bored, 8-inch	302	273	46			Gas		300.00	Domestic	
221	D. C. Nidever	do	M-12	1897	Bored, 10-inch	296	267	101			Steam	*1,200.00		Irrigation	100
222	R. E. Damer	do	M-12		Bored, 7-inch	300	269	60			Wind			Domestic	
223	B. W. Daucer	do	M-12		do	302	269				Hand			do	
224	Daucer Bros	do	M-12	1898	Bored, 10-inch	305	269	103			Steam	*1,300.00		Irrigation	
225	P. F. Cogswell	do	N-13	1892	Bored, 12-inch	305	272	137			Gas			do	
226	Yock ranch	do	N-12		Bored, 7-inch	320	274	50			Hand			Domestic	
227	Piercy ranch	do	N-11	1898	Bored, 12-inch	335	277	129			Steam		2,500.00	Irrigation	
228	do	do	N-11	1894	Bored, 10-inch	335	277	107			do				
229	D. F. Pearson ranch	do	N-11	1896	Bored, 12-inch	325	273	150			Gas	300.00	1,400.00	do	150
230	do	do	N-11	1895	do	325	273	114			do	250.00			
231	Sumar ranch	do	N-10	1899	Dug, 4 by 4 foot.	344	277	72			Hand			Domestic	
232	Stucker estate	do	L. M-11		Bored, 4-inch	312	274	40			Wind			do	
233	M. A. Papon	do	M-11		Bored, 7-inch	320	276	46			do			do	
234	W. Snoddy	do	M-10		do	340	289	52			do			do	
235	do	do	M-10	1899	Bored, 12-inch	345	291	247			Steam	525.00	1,700.00	Irrigation	
236	Alvarida Water Co.	Santa Anita	M-10	1899	do	385	325	209			Gas		4,000.00	do	25
237	A. J. Averell	do	M-7	1899	Dug, 4 by 7 foot, 218 feet; bored, 10-inch, 178 feet.	511	305	396			Steam?		16,000.00	do	25
238	Mr. Boyd	do	M-7		Bored, 12-inch	530	310	350						Not used	
239	Harry R. Stocker	do	M-7	1902	Dug, 4 by 6 foot.	550	514	49			Gas?		1,150.00	Irrigation	†18
240	E. J. Baldwin	do	K-8		Bored, 7-inch	630	625	270			Compressed air, artesian.				
241	do	do	K-8		Bored, 10-inch	630	627	450			do			Irrigation	
242	do	do	K-8		Bored, 7-inch	610	-611	300			Artesian			do	
243	do	do	K-8		do	618	608	130			Hand			Domestic	
244	do	do	K-8		do	618	612							Not used	
245	do	do	K-8		do	585	585	225			Artesian				
246	do	do	K-8	1902	Dug, 4 by 6 foot, 71 feet; bored, 7-inch, 289 feet.	614	594?	480			Steam, air			Irrigation	†40

Wells in the foothill belt of southern California—Continued.

PASADENA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
247	E. J. Baldwin	Santa Anita	K-8		Bored, 7-inch	600	601	300			Artesian			Domestic	
248	do	do	K-8		do	614	614	300			do				
249	do	do	K-8		do	605	606	300			do			Domestic	
250	do	do	K-8		do	600	601	300							
251	do	do	K-8		do	596	599	300			Artesian			Stock	
252	do	do	K-8		do	593	595	300			do			do	
253	do	do	K-8		do	590	594	300			do			Not used	
254	do	do	M-7		Dug, 6 by 6 foot.	570	528	57			Gas			Irrigation	†60
255	do	do	M-6		Dug, 3 by 5 foot.	750	709	62							
256	T. E. Yerxa	do	M-7		Dug, 4 by 6 foot.	745	577	178			Gas	$1,300.00	$1,400.00	Irrigation	10
257	J. C. Pegler	do	M-6	1897	do	777	569	236			do		3,000.00	do	10
258	Sierra Madre Water Co.	do	M-7	1900	Dug, 5 by 6 foot, 136 feet; bored, 12-inch, 223 feet.	675	552	359			Gas (2 plants)	2,500.00	6,000.00	do	20
259	Graves & Bean	San Pasqual	G-9		Bored	750	701	204			Flows into tunnel.				
260	do	do	G-9		do	752	703	256			do			Irrigation	†20
261	do	do	G-9		do	755	703	212							
262	Sunny slope ranch	San Anita	J-9		Bored, 7-inch	618	615	117			Wind				
263	do	do	J-9		do	620	616	160						Not used	
264	do	do	J-9		do	618	604	210						do	
265	do	do	I-9		do	618	604	200+			Tapped below surface.				
267	J. S. Maderis	do	J-8	1901	do	645	621	200			Gas	350.00	550.00	Domestic; irrigation.	
268	Fred W. Elleby	do	J-8		Bored, 8-inch	648	614	112			do			do	11
269	E. Messenger	Sec. 9, T. 1 S., R. 12 W.	G-11	1900	Bored, 9½-inch	525	305	340			Gas?	600.00	1,495.00	do	12
270	F. J. Culver	San Pasqual	E-9		Bored, 7-inch	768	725	105							
272	M. M. Langford	do	F-8		do	800	734	73			Wind			Domestic	
273	E. J. Baldwin	do	K-8		do	650					Compressed air.			Irrigation	
274	Joe Agure	Paso de Bartolo	J-17		Dug, 3½ by 3½ foot.	175	164	11			Hand			Domestic	
275	A. Genen	do	J-11		Bored, 4-inch	175	185	34			do			do	
276	T. P. Passons	do	J-17		do	185	173	43						do	
277	A. Dixon	do	J-17		do	180	160	64			Hand			do	

278	D. A. Sugg	do	I-17		Dug, 3½ by 3½ foot.	180	161	20			do				
279	K. Cohn	San Antonio	I-17	1899	Bored, 12-inch	220	180	245			Steam			Irrigation	200
280	do	do	H-17		Bored, 7-inch	198	154	146			Wind			Domestic	
281	W. C. Rushing	do	H-17	1902	Bored, 5½-inch	200	148	57			Hand	45.00		do	
282	Vail, Gates & Co.	do	H-17		Bored, 12-inch	195	150	500			Electric motor			Irrigation	100
283	Bicknow & White	do	G-16		Bored, 7-inch	205	133	100			Wind			Domestic	
284	Mr. Pendina	do	F-16		do	200	154	65			do			do	
285	George Peterson	do	E-16		do	200	158	100			do			do	
286	E. G. Green	do	D-16		Bored, 8-inch	200	150	65			do			do	
287	Mr. Shaffinger	Sec. 31, T. 1 S., R. 12 W.	E-15			310	175	165			do			do	
288	I. W. Hellman	Sec. 32, T. 1 S., R. 12 W.	F-15	1903	Bored, 10-inch	285	157	250			Gas	512.00	300.00	do	
289	J. M. Clyman	Sec. 31, T. 1 S., R. 12 W.	E-15		Bored, 2-inch	320	220	115			Wind			do	
290	P. H. Matthews	Sec. 32, T. 1 S., R. 12 W.	E-15		Bored, 7-inch	295	170	335			do			Domestic; irrigation.	
291	Calvary Cemetery	San Antonio	E-16		Bored, 10-inch	220	160	213			Gas			Irrigation	
292	F. Escallier	do	D-16	1903	Bored, 12-inch	225	152	171			Not installed				
293	L. Pilaria	do	D-16		Bored, 7-inch	280	160	140						Not used	
294	G. W. Shields	Sec. 1, T. 2 S., R. 13 W.	D-16		do	315	165	180			Wind			Domestic	
295	F. C. Randolph	Sec. 31, T. 1 S., R. 12 W.	D-15		do	330	224	110			do			do	
296	B. J. Nettleton	San Antonio	D-16		do	215	157	120			do			do	
297	I. O. O. F. cemetery	Sec. 1, T. 2 S., R. 13 W.	C, D-16	1899	Bored, 9-inch	250	144	248			Gas	500.00		Irrigation	†3
301	C. Spect	Los Angeles city	B-12		Bored, 7-inch	333	303	38			Wind			Domestic	
302	Eli Taylor	do	B-12	1894	do	395	335	54			do	100.00		do	
303	Armour Packing Co.	do	B-12	1902	Bored, 8-inch	340	310	55			Electric motor			do	†3
304	Mrs. Norman	do	A-11		Bored, 7-inch	340	328	40			Wind			do	
305	Mary Everett	do	A-11		Dug, 5 by 5 foot.	450	420	29						Not used	
306	Mrs. F. Dupuis	do	B-11	1885	Bored, 8-inch	350	327	9			Wind			Domestic; irrigation.	
307	Mr. Mackay	do	B-11	1880	Bored, 7-inch	360	310	20			do			Not used	
308	Chinese vegetable garden.	San Rafael	A-11		Dug, 4 foot diameter.	340	331	11			Hand			Domestic	
309	L. Shilker	do	A-11	1890	Bored, 8-inch	360	344	40			Wind			do	
310	Fraternal Club	do	A-11		Dug, 2 by 2 foot.	375	344	34			do			do	
311	F. Douillard	do	A-11		Dug, 6 by 6 foot.	450	446	10			do			do	
312	Joe Hunter	do	A-10		Dug, 4 by 4 foot.	375	366	21			Hand			do	
313	V. & E. Sentona	do	A-10		Bored, 7-inch	370	353	30			Wind			do	
314	Samuel Hunter	do	A-10		do	375	357	43			do			do	
315	L. Salzgeber	do	A-11	1902	Bored, 12-inch	350	336	97			Gas	150.00	1,400.00	Irrigation	†90
316	J. W. Cook	do	A-10		Bored, 7-inch	400	361	60			Wind			Domestic	
317	Mr. Glassale	do	A-10			410	359	90			do			do	
318	Jack Greggians	do	A-10		Bored, 7-inch	390	372	60			do				
319	Conrad Winter	do	A-10		do	390	381	45			do			Domestic	
320	Silas Hollenbeck	do	A-8		Dug, 4-foot diameter.	540	512	46			do			do	
321	A. Workman	do	A, B-8, 9.	1901	Bored, 12-inch	600	535	171			Gas	427.00	1,000.00		8

Wells in the foothill belt of southern California—Continued.

PASADENA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
322	A. Workman	San Rafael	A-9		Dug, 8 by 8 foot.	530	499	40							
323	T. Brooks	do	B-9	1903	Bored, 8-inch	510	492	140						Not used	
324	Cromwell Galpin	do	B-9	1899	Bored, 7-inch	540	510	66			Gas	$120.00	$600.00	Irrigation	6
325	S. G. Spear	do	A-10	1887	Dug, 6 by 6 foot.	450	395	70			Wind			Domestic	
326	A. Glassell	do	B-9	1880	Bored, 7-inch	495	495	80			Artesian	80.00		Domestic; irrigation.	
327	do	do	B-9		Bored, 7-inch (2 wells).	490	490	210, 140			do			do	
329	O. D. Nagle	do	A-10	1901	Dug, 4 by 4 foot.	395	380	75			Wind, gas			do	
330	W. R. White	do	C-8, 9	1899	Bored, 7-inch	550	510	142			Gas			do	20
330a	do	do	C-8, 9	1902	Bored, 12-inch	550	510	113			do			do	
331	J. A. Gates	do	C-8		Bored, 12-inch (2 wells).	550	510	144			do			Irrigation	20
332	G. W. Benson	do	B-8		Dug, 3-foot diameter.	590	530	100			Wind			Domestic	
333	P. Young	do	B-8	1901	Bored, 12-inch	570	511	140			Gas			Irrigation	6
334	J. L. Hickson	do	C-8		Bored, 7-inch	640	610	86			do			do	
335	L. F. Meyers	do	C-8		Bored, 9-inch	590	540	78			Wind			Domestic	
336	A. M. Torrey	do	C-8, 9		Bored, 8-inch	650	596	86			do			do	
337	C. E. Thom	do	A-7		Bored, 12-inch	635	555	170			Gas			Domestic; irrigation.	16
338	McWhorter Bros.	do	A-10		Bored, 7-inch	375	351	50			Wind			Domestic	
339	E. Leavitt	do	A-7	1902	Dug, 4 by 4 foot, 100 feet; bored, 9½-inch, 147 feet.	625	438	247			Gas	500.00	1,500.00	Domestic; irrigation.	14
340	F. M. Beers	do	A-8		Dug, 3 by 4 foot.	585	435	180			do			do	1½
341	Dr. Horace Wing	do	A-8	1900	Dug, 4 by 4 foot, 105 feet; bored, 14-inch, 82 feet.	565	459	187			do			Irrigation	9
342	Mr. Lukens	do	A-8		Dug, 4 by 5 foot, 153 feet; bored, 12-inch, 115 foot.	605	448	268			do			do	16
343	Hall & Russell	do	A-7	1903	Bored, 12-inch	640	550	105			do			do	15
344	Dodge, Sinclair & Co	do	A-7	1899	Dug, 4 by 5 foot.	655	595	78			do			do	10

345	W. A. Norton	do.	B-7		Bored, 7-inch	740	655	145			Wind			Domestic	
346	W. Llewellyn	do.	A-7		Dug, 4 by 5 foot.	655	557	102			Gas			Irrigation	10
347	Independent Water Co.	do.	A-7	1902	Dug, 4 by 5 foot, 60 feet; bored, 12-inch, 287 feet.	665	565	347			do.	1,000.00	1,200.00	Domestic; irrigation.	22
349	Charles Moser	do.	A-8		Dug, 75 feet; bored, 10-inch.	520	445				do.			Irrigation	
350	John Ungerland	do.	A-9	1901	Dug, 4 by 4 foot.	540	500	60			do.			Domestic; irrigation.	
351	Tropico Water Co	do.	A-8	1897	Bored, 12-inch	535	439	150			do.	400.00	2,500.00	do.	70
352	George M. Payne	Los Angeles city	A-11	1902	do.	340	331	50			do.	89.00	1,000.00	Irrigation	20
353	C. E. Thom	San Rafael	B-5	1903	Dug, 6 by 6 foot.	950	913	49			do.	490.00		Not completed	
354	do.	do.	A-7		Dug, 6 by 7 foot.	700	660	60			do.			Domestic; irrigation.	15
355	do.	do.	A-7		Dug, 5 by 6 foot.	700	660	100			do.			do.	10
356	Brooks Bros	Los Angeles city	A-12	1904	Bored, 12-inch	335	327	109			Not installed				
357	L. M. Sifford	do.	B-12	1898	Dug, 3 by 3 foot.	340	322	18	47		Wind			Not used	
358	Sarah Brown	do.	B-12	1892	Dug, 3½ by 4 foot	340	307	35	48	68	do.			do.	
359	Los Angeles Stone and Sewer Pipe Co.	do.	B-12	1903	Dug, 5 by 8 foot.	345	312	45			Steam			Manufacturing	
360	L. D. Drake	do.	B-13		Bored, 6-inch	345	312	60?			Wind			Domestic	
361	Joe Cuceia	do.	B-13	1895	Bored, 2-inch	300	287	22			do.			do.	
362	Mrs. M. S. Helm	do.	B-13	1890?	Dug, 3 by 3 foot.	300	283	18	80	66	do.			Not used	
363	Peter Capro	do.	B-13	1897	Dug, 3 foot diameter.	285	276	9	64	66	do.			Domestic	
364	Los Angeles Brewing Co.	do.	B-13		Bored, 7-inch (2 wells).	290	280	57?	38	68	Steam			Brewery	45
364a	do.	do.	B-13		Bored, 12-inch (2 wells).	290	280	60?	38	68	do.			do.	
365	Mrs. J E. Kennedy	do.	C-13	1894?	Bored, 7-inch	315	273	98	96		Wind			Domestic	
366	L. M. Gilman	do.	C-13		do.	350	294	100+			do.			Not used	
367	A. T. Leonard	do.	C-13	1890?	do.	340	295	153	74		do.			Domestic	
368	Jessie P. Monte	do.	C-14	1890?	Dug, 2½-foot diameter.	300	289	22	140		do.			do.	
369	J. G. Bell	do.	C-15		Dug, 3-foot diameter.	340	276	71	91	68	do.			Not used	
370	Diamond Hill Floral Co.	do.	B-15	1892?	Dug, 5-foot diameter.	325	275	91	47		do.			do.	
371	J. C. Putnam	do.	B-16	1895?	Bored, 7-inch	310	Dry.	98			do.			No water	
372	Charles Karstadt	do.	A-16	1894?	Bored, 6-inch	225	115?	125	45		do.			Domestic	
373	J. Eustace	do.	A-16	1896	Bored, 7-inch	240	188?	93	51		do.			do.	
374	Pacific Electric Rwy. Co.	do.	A-15		Bored, 12-inch (3 wells).	245	159	100+			Not installed				
375	Inman Poulson Lumber Co.	do.	A-17		Bored, 12-inch	225	150	165			do.				
376	J. J. Maxey	Sec. 9, T. 2 S., R. 13 W.	A-17	1885	Bored	215	141		50		Wind			Domestic; stock	
377	L. Hooper	do.	A-17	1874	Bored, 7-inch	215	167	50	44		do.			Domestic	
378	Miss J. R. Dorsey	do.	A-17	1901	Bored, 12-inch	210	140	211	53	65	Gas			Irrigation	†65
379	Miss M. J. Cameron	do.	A-17	1899?	Bored, 7-inch	200	126	90?	49		Wind			Domestic	
381	Mrs. R. J. Withers	Sec. 10, T. 2 S., R. 13 W.	A-17	1902	Bored, 9-inch	195	135	206	43		do.			Domestic; irrigation.	

Wells in the foothill belt of southern California—Continued.

PASADENA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (miner's inches).
382	W. S. Holland	San Antonio	B-17	1902	Bored, 10-inch	195	125	155	50		Wind			Domestic	
383	Moore Bros	do	B-17	1902	Bored, 12-inch	190	119?	226		60	Compressed air			Irrigation	} †100
383a	do	do	B-17	1904	do	190	119?	287			do			do	
384	Peter Scott	Sec. 10, T. 2 S., R. 13 W.	B-17	1900?	Bored, 7-inch	195	130	75?	48		Wind			Domestic	
385	J. W. Kniffin	do	B-17	1902	Bored, 10-inch	205	137	215	64		Gas, wind			Domestic; stock.	
386	Hercules Oil Refining Co.	San Antonio	B-17	1902	Bored, 9-inch	205	145	280	40	60	Compressed air			Manufacturing	
387	W. M. Stephens	do	B-17	1903	Bored, 7-inch	210	142	175	43		Wind			Stock	
388	David Vaccero	Sec. 9, T. 2 S., R. 13 W.	A-17	1902	do	210	141	100	53		do	$100.00	$35.00	Domestic	
389	James Sweet	Sec. 10, T. 2 S., R. 13 W.	A-17	1901	do	200	133	104	53		do			Domestic; irrigation.	
390	C. Smith	San Antonio	B-17	1902	do	190	129	100			do			Domestic	
391	J. H. Van Nest	do	B-17	1900	Dug, 62 feet; bored, 10-inch, 127 feet.	190	125	189	42	62	Steam	450.00	1,500.00	Irrigation	40
392	J. L. Graham	do	B-17	1899	Dug, 5 by 5 foot, 49 feet; bored, 12-inch, 151 feet.	185	125	200	43	61	Gas			do	†30
393	A. Koppe	do	B-17	1903	Dug, 5 by 5 foot, 65 feet; bored, 12-inch, 30 feet.	195	144	95	49		do		1,850.00	do	40
394	Lada Terry	do	B-17		Bored, 12-inch	195	136	110	46		Wind			Stock	
395	Mrs. Anderson	do	C-17	1879?	Bored, 7-inch	190	135	85	53	62	do			Domestic; stock.	
396	A. A. Gast	do	C-17		do	185	125	100	47		do			Domestic	
397	J. G. Evans	do	B-17	1900	Dug, 6 by 6 foot, 40 feet; bored, 12-inch, 116 feet.	185	127	156	41	62	Gas			Irrigation	†15
398	do	do	B-17	1901	Bored, 12-inch	185	127	202	40	61	do			do	†15
399	L. A. Turner	do	C-17		Bored, 7-inch	175	130				Electric motor			do	
400	B. Beone	do	C-17	1900	do	185	138	98	47		Wind				
401	Chong Wong & Co.	do	C-17		do	185	145	63	51	62	do			Domestic; irrigation.	
402	E. G. Greening	do	D-17		Bored	175			27	68	Electric motor			Irrigation	†75
403	J. D. Hart	Los Angeles city	C-16	1901	Bored, 7-inch	210		100	53		Wind			Domestic	
404	Mr. MacHaley	do	B-16	1900	do	220	100	88	44		Gas			Domestic; stock.	†1

405	Mr. Appel	do	B-17		do	220	160	93	46		Wind			do	
406	P. T. Sullivan	do	C-16	1882	Bored, 9-inch	240	148	140			do			Domestic	
407	J. O. Sullivan	do	G-16	1904	Bored, 10-inch	215		229			Not installed				
408	J. J. Adams	do	C-16	1899	Bored, 7-inch	215	157	150	38		Wind			Domestic; stock	
409	George E. Platt	San Antonio	D-16	1899	Bored, 12-inch	220	151	214	37		Gas			Irrigation	†70
409a	do	do	B-16	1902	Bored, 16-inch	220	151	218	37		do			do	
410	B'nai B'rith cemetery.	do	E-16	1902	Bored, 14-inch	200	150	200			Electric motor			do	†8
411	Laguna Land and Water Co.	do	H-17	1902	Bored, 12-inch	190	148	450	34		do			do	†200
412	J. H. Barbour	do	H-17	1903	Bored, 7-inch	200	151	130	31		Gas	100.00	300.00	Domestic; stock	
413	G. W. Scott	Paso de Bartolo	I-17	1904	Bored, 12-inch (2 wells).	160	150	107	23	64	do	500.00	1,500.00	Irrigation	†200
414	Louis Farmer	Potrero de Felipe Lugo.	L-15		Bored, 7-inch	225	216	20	20	62	Wind			Domestic	
415	F. F. Pellissier	La Puente	M-15		Bored, 12-inch	260	248		29		Gas			Irrigation	
416	John Waggoner	Paso de Bartolo	L-17	1900	Bored. 4-inch	235	218	48			Wind			Domestic; stock; irrigation.	†200
417	Rincon Irrigation Co.	do	L-16	1900	Bored, 10-inch	235	219	160	24	70	Gas			Irrigation	†110
418	J. D. Durfee	Potrero de Felipe Lugo.	L-15	1892	Bored, 7-inch	240	232	50	20	60	Wind			Domestic	
420	P. Cartota	San Rafael	A-11	1904	Bored, 12-inch	345	327	120			Gas			Irrigation	
421	J. N. Witham	do	A-8	1902	Bored, 9½-inch	545	435	170			do	350.00	650.00	do	
422	E. M. Ross	do	B-6	1897	Bored, 12-inch	805	797	119			do			do	†12
423	L. G. Allen	La Canada	A-3	1894	Dug. 5 by 5 foot.	1,200	1,164	43			do			do	†8
424	A. C. Palfrey	San Rafael	B-4		Dug	1,225	1,033	214			do			do	†12
425	N. B. Huff	do	A-8	1904	Dug, 4 by 5 foot, 80 feet; bored, 9-inch, 110 feet.	515	435?	191			do			do	
426	Mr. Laux	do	C-8	1901	Bored, 12-inch	650	605?	200			do			do	†5
427	Mrs. Mary Hunter	Los Angeles city	C-12		Dug, 4 by 4 foot.	390	358	34	35		Wind			Domestic; irrigation.	
428	Mrs. E. M. Winston	San Rafael	C-11	1903	Bored, 7-inch	505	461	85	25		do			Domestic	
429	Charles Wenrich	do	D-10	1899	Dug, 5 by 5 foot.	575	563	40	40		do			do	
430	M. H. Dunn	do	C-9	1902?	Dug, 4 by 4 foot; bored, 7-inch.	580	564	150	21		do			Domestic; irrigation.	
431	J. W. Means	do	C-10	1896?	Dug, 4-foot diameter.	572	521	55	52		do			Domestic	
432	Pasadena Lake Vineyard Land and Water Co.	San Pasqual	F-6	1896	Dug. 6 by 10 foot; bored, 12-inch.	930	744	700	18		Steam	13,632.00		Domestic; irrigation.	
433	Pasadena Lake Vineyard Land and Water Co. and Pasadena Land and Water Co.	do	E-5	1899	Dug, 6 by 8 foot	1,000	975	55	23	64	Gas			do	25
434	do	do	E-5	1903?	Dug, 175 feet; bored, 200 feet.	1,140	965?	375	20	63	Compressed air		152.80	do	154
434a	do	do	E-5	1903?	Dug, 175 feet; bored, 400 feet.	1,140	965?	575	20	63	do				

Wells in the foothill belt of southern California—Continued.

PASADENA QUADRANGLE—Continued.

No. of well.	Owner.	Location.	Map location.	Year completed.	Class of well.	Elevation of surface (feet)—approximate only.	Elevation of water (feet).	Depth of well (feet).	Solids per 100,000.	Temperature of water (°F.).	Method of lift.	Cost of well.	Cost of machinery.	Use of water.	Quantity of water (Miner's inches).
435	North Pasadena Land and Water Co.	San Pasqual	E-5	1893?	Dug, 4 by 8 foot.	1,125	980	160	21	65	Steam	a$20,145.00		Domestic; irrigation.	†30
436	Lincoln Avenue Water Co.	do	E, F-4		Dug, 5 by 7 foot, 236 feet; bored, 10-inch, 256 feet.	1,200	955	492	25	65	do			do	†25
437	North Pasadena Land and Water Co.	do	E-6		Dug, 6 by 9 foot, 110 feet; bored, 14-inch, 30 feet.	1,040	960	140	22	67	do	(b)		do	†50
438	H. E. Huntington	Santa Anita	I-8	1903	Bored, 10-inch	730	615	300			Electric motor			do	†18
439	Lloyd & Wood	do	L, M-7	1900	Dug, 4 by 6 foot	650	543	122	23		Gas			Irrigation	†12
440	E. J. Baldwin	do	K-9		Bored	505		300			do			do	
441	A. Scott Chapman	do	J-8	1892	Bored, 7-inch	660	620	450	24		Steam			do	†30
442	A. B. Chapman	do	J-8			630	617		19		Gas			do	
443	do	do	J-8	1898	Bored, 10-inch	610	606	560	18		do			do	150
444	do	do	J-9		Bored, 7-inch	606	606	156	19	71	Artesian			do	†4
445	do	do	J-8		Bored, 10-inch	615		400			Electric motor			do	†70
446	A. S. Chapman	do	J, K-8			600					Gas				†25
447	G. P. Wegener	Sec. 16, T. 1 S., R. 12 W.	G-12	1903	Bored, 10-inch	475	250	330	21		do			Domestic; irrigation.	†15
448	Pasadena Land and Water Co.	San Pasqual	G-9	1904	Bored, 12-inch	760	721?	215	23		Steam			Domestic	†90
448a	do	do	G-9	1904	do	760	721?	254	23		do			do	
448b	do	do	G-9	1904	do	760	721	256	23		do			do	
449	Graves & Brean	do	G-9	1904	Bored, 10-inch (3 wells).	765	725?	250-700			Flow into tunnel.			Irrigation	†60
449a	do	do	G-9		Bored, 10-inch (6 wells).	765	725?	250-700			do			do	
450	H. C. Allen	do	G-9	1891	Bored, 10-inch	755		130	27	71	Gas			do	2
451	Alhambra Addition Land and Water Co.	do	G-9	1896?	Bored, 6-inch (6 wells).	700	675	120	23		Compressed air			do	†100
452	Huntington Land and Improvement Co.	Sec. 3, T. 1 S., R. 12 W.	G-9	1901	Bored, 10-inch	600	588	417	22		Electric motor			Domestic; irrigation.	†68

453	do	Sec. 35, T. 1 N., R. 12 W.	I-9		Dug, 4 by 6 foot.	610	590		17	69	do			Irrigation	20
454	do	do	I-9	1904	Dug, 7-foot diameter; bored, 14-inch.	635	602	400			do			do	†100
455	A. E. Johnson	Potrero Grande	J-13	1899	Bored, 8-inch	260	258	430	20		Gas			do	66
456	Mr. McCloud	Sec. 13, T. 1 S., R. 12 W.	I-12	1904	Bored, 10-inch	335	274?	300	27		do			do	†30
457	Warde Bros	do	J-12	1904	do	340	280	375			do			do	†125
458	T. P. Herbert	Sec. 20, T. 1 S., R. 11 W.	L-13	1904	Bored, 12-inch	260	249	302	17	68	do			do	†60
459	G. Kallmeyer	San Francisquito	M-12	1904	do	300	267	127	22		do			do	†40
460	G. R. Green	do	M-11	1902	do	310	270	130	21	64	do			do	†155
461	Frank Proctor	do	M-12	1901	Bored	315	265	140			do			do	†100
462	C. H. Rhodes	San Rafael	G-9	1904	Dug, 5 by 5 foot, 50 feet; bored, 10-inch, 85 feet.	740		135			Steam			do	
463	Frank Jones	Santa Anita	J-8	1903	Bored, 12-inch	650	618	236			Compressed air			do	18
464	Jack Butler	do	J-8	1904	Bored, 10-inch	645	619	198			Gas			do	†30
465	Sunny Slope Water Co.	do	J-9	1903	do	610	605?	380			Electric motor			do	
466	Pasadena Land and Water Co.	San Pasqual	E-7	1901	Dug, 6 by 8 foot.	775		75			Gas, steam			Domestic	†85
467	S. Richardson	do	G-10	1898	Bored, 8-inch (2 wells); 12-inch (2 wells).	650	580	150-180			Steam			Irrigation	†75
468	East Pasadena Land and Water Co.	do	G-8	1902?	Dug, 6 by 8 foot, 90 feet; bored, 12-inch (4 wells)	785	715	630-734			do			Not used	†100
469	Marengo Water Co.	do	F-9	1901	Bored, 12-inch (3 wells).						Gas, electric motor (2 plants).			Irrigation	†120
470	George S. Patton	do	G-9			725					Gas			do	
471	do	Santa Anita	H-9		Dug, 40 feet	675	660	300-400			Electric motor			do	†100
472	Huntington Land and Improvement Co.	do	H, I-9			650	612	200			do			Domestic; irrigation.	†7
473	Pasadena Land and Water Co.	San Pasqual	E-9		Dug, 6 by 8 foot.	750	710	70			do			do	
474	J. T. Eldridge	do	I-8		Bored, 7-inch	650	607	140			Gas			do	
475	Titus ranch	do	J-9		do	620	608	132			Not raised			Not used	
476	G. B. Renfro	Sec. 18, T. 1 S., R. 11 W.	K-12		do	300	279	46			Wind			Domestic	
477	Mr. Beck	San Francisquito	L-12		do	275	260				do			do	
478	M. Ritter	do	L-13		do	275	257	60			Hand			do	
479	Mrs. McClure	Sec. 21, T. 1 S., R. 11 W.	L-13		do	265	251	61			Wind			do	
480	E. J. Baldwin	Santa Anita	K-8		Bored, 12-inch	535	535	500			Artesian, gas			Irrigation	†75

[a] Including No. 437.

[b] Including No. 435.

INDEX.

A. Page.
Absorption, rate of 28–29
  relation of, to character of soil 26–28
    to floods 25–26
Alhambra Addition Water Co., irrigation plant of 120
Alkire tunnel, description of 88
Alley, Charles, well of, fluctuations in 61–62
Allin, T. D., aid of 67
Alluvium, water in 11
  See also Earlier alluvium; Later alluvium.
Alvarado, M., water rights of 80
American Beet and Sugar Co., wells of 145, 146–147, 148
Anaheim, rainfall at 19
  underground water at, fluctuations of 54
Arroyo Seco, description of 9
  development in 125, 128
  flow of 123
  panoramic view on 8
  wells on 125
Artesian areas, maps showing Pocket.
Artesian Belt Water Co., irrigation plant of 95–96
Artesian water, geographic extent of 54
  geographic extent of, maps showing Pocket.
  use of, growth of 7
Azusa, flow at 99–101
Azusa Agricultural Water Co., irrigation plant of 105–106
Azusa Irrigating Co., irrigation plant of 101–102
  well of, fluctuations in 59

B.
Baker & Son, well of 45
Baldwin, T. J., irrigation plants of 115–116
Banbury well, description of 128
Basins, depths of 33
  floors of 31–32
  See also Reservoirs, underground.
Beardslee Water Ditch Co., irrigation plant 110–111, 113–114
Big Dalton Canyon, water of 107–108
Bradford street well, description of 131, 132, 133
Brown, W. P., well of, section of, figure showing 40
Bunker Hill dike, location of 53

C.
Canals, location of, maps showing Pocket.
Canyon Ridge Water Co., irrigation plant of 87
  well of 143
Canyon Water Co. of Pomona, irrigation plant of 80–81
Cathcart, R., well of 85
Chapea Water Co., irrigation plant of 119
Chino, artesian belt near 39–42
  wells at and near 32, 40, 41, 145–148
Chino Creek, flow of 40
Chino Land and Water Co., irrigation plant of 89–90
  wells of 147, 148, 151
Cienaga Land and Water Co., history of 94
Citizens Light and Power Co., irrigation plant of 89
  wells of 150
Citrus Belt Water Co., irrigation plant of 106
Clapp, W. B., absorption measurements by 28
Claremont, water supply of 89
Claremont Cooperative Power Co., irrigation plant of 88
  wells of 150
Coast Range, coastal plain west of, study of 7
Columbia Land and Water Co., irrigation plant of 106–107
Conservation. *See* Waters.
Consolidated Water Co. of Pomona, irrigation plant of 84–85
  wells of 150, 151
Copeland well, description of 128
Covina Irrigating Co., irrigation plant of 98, 102–105
  wells of 45
Cucamonga, wells at, data on 142–144
Cucamonga fan, absorption work on 26
Cucamonga Fruit Land Co., history of 72–73
Cucamonga lands, irrigation of 71–74
Cucamonga Plains, description of 9, 14
  gravel in, depth of 33
Cucamonga quadrangle, artesian map of Pocket.
  irrigation in 139
  irrigation map of Pocket.
  wells in, data on 140–151
Cucamonga tunnel, section of, figure showing 34
Cucamonga Water Co., history of 71–73
  irrigation plant of 73–74
  wells of 142–143
    figure showing 35
Culver well, yield of 131, 132, 133
Currier, A. T., irrigation plant of 90
  wells of 149, 152
Currier Tract Water Co., irrigation plant of 90
  well of 152
Cypress Avenue Water Co., irrigation plant of 110

D.
Dalton, wells near, data on 156, 159–160
Dams, submerged, construction of 52
  view of 52
Day Canyon, flow in 68
Deacon, Sidney, well of, fluctuations in 60
Deacon wells, description of 45–46

Page.
Deer Canyon, flow in............ 69
Del Monte cienaga, location and character of 35
  water of............ 82-83
Del Monte Irrigation Co., irrigation plant of 81-82
  wells of............ 149, 151
Devils Gate, development at... 52, 126-128, 130-131
  springs at............ 52
  submerged dam at, view at............ 52
  view of............ 52
  wells at............ 125
Dikes, character of............ 38
  origin of............ 11
Duarte, irrigation plants at............ 110-114
  wells at, data on............ 154
Duarte Mutual Irrigation and Canal Co., irrigation plant of............ 110-113

E.

Earlier alluvium, description of............ 11-12, 44
  dip of............ 12, 35
  occurrence of............ 35, 43-44
  underflow deflected by............ 12, 35, 36, 44
  uplift of............ 11-12
  water in............ 11, 35-37
East Pasadena Land and Water Co., wells of............ 52-53
East Whittier Land and Water Co., well of............ 31-32, 49
  well of, section of, figure showing............ 32
Eaton Canyon, flow from............ 117
Eddy tunnel. *See* Cucamonga tunnel.
El Molino Canyon, flow of............ 120
Elmonte, well at............ 49
Equivalents, useful, list of............ 139
Erosion, work of............ 14-15, 18, 30-31
Etiwanda Canyon, flow in............ 68
Etiwanda Water Co., irrigation plant of... 67-68
Euclid Avenue Water Co., irrigation plant of............ 120-121
  well of............ 53
Evaporation, estimate of............ 29

F.

Fans, alluvial, origin of............ 30-31
Fault lines, description of............ 16
Ferry, William, well of, fluctuations in..... 60
Fickewirth, Edward, well of............ 49
  well of, section of, figure showing............ 50
Field work, description of............ 7
Firth, E., well of, fluctuations in............ 58-59
Fish Creek, water of............ 111-112
Fish, A. J., jr., work of............ 139
Floods, absorption of............ 25-26
  waste by............ 22
Foothill belt, area of............ 8
  importance of............ 8
  irrigation in............ 8
  land in, value of............ 8
Forests, relation of, to run-off............ 22-23, 25
Frostless Belt Water Co., irrigation plant of 96-97
Fryer, J. M., well of............ 152
Fryer, Mrs. S. L., well of............ 152
Fryer ranch, well on............ 152

G.

Garvey Water Co., irrigation plant of.... 119-120
Geography, description of............ 8-9, 13
  See also Physiography.

Page.
Geologic history, outline of............ 15
Geology, relation of, to underground waters............ 10-13
Gird well, section of, figure showing............ 39
Glaciation, features of............ 30-31
Glenarm street wells, description of............ 133
Glendora-Azusa Water Co., irrigation plant of............ 108-109
Glendora Water Co., history of............ 137
Graves & Bean, wells of............ 51, 53
Ground water, level of, fluctuations in..... 54-67
  level of, maps showing............ Pocket.
Ground-water districts, descriptions of.... 33-54
Grunsky, C. E., formula of, for flow of wells............ 137

H.

Hall, W. H., on irrigation............ 67
Henderson, P. S., well of............ 140
Hermosa Water Co., irrigation plant of.... 68-70
  well of............ 142
Historical geology, outline of............ 15
Howell well, description of............ 42
Hydrographic contours, maps showing. Pocket.

I.

Igneous rocks, water in............ 16
Indian Hill, gravel of............ 12, 34
Ioamosa Water Co., irrigation plant of..... 70-71
Irrigation Company of Pomona, irrigation plant of............ 82-83
  wells of............ 45, 82, 151
Irrigation enterprises, description of...... 67-137
  maps showing............ Pocket.
  summary of............ 136
Irwindale, irrigation plants at............ 109-110
Irwindale Land and Water Co., irrigation plant of............ 109

K.

Kingsley Tract Water Co., irrigation plant of 85-86

L.

La Canada, well at, data on............ 173
Lake Vineyard, wells at............ 125
La Puente, wells at............ 154, 157, 159, 160
Later alluvium, water in............ 11, 12, 35-37
Laverne, irrigation near............ 92-93, 96
Laverne Irrigating Co............ 92-93
Laverne Land and Water Co., irrigation plant of............ 92
Lemon, wells near............ 42
Lincoln Avenue Water Co., irrigation plant of............ 117-118
Linnastruth, B., wells of............ 152
  wells of, fluctuations in............ 57
Lippincott, J. B., table by............ 139
Literature, description of............ 7-8
Little Dalton Canyon, waters of............ 108
Little Santa Anita Canyon, waters of.... 115-116
Lorbeer well, description of............ 41
  section of, figure showing............ 41
Lordsburg, irrigation near............ 91-92
  wells near, fluctuations in............ 61-62
Lordsburg Water Co., irrigation plant of... 91-92
Los Angeles, rainfall at............ 19, 21
  wells at............ 169, 171-173
Los Nogales, wells at, data on............ 160
Los Robles Canyon, waters of............ 120-121

M. Page.

McClintock, Lee, & St. Clair, well of 42
Maps, comment on 138
Maps, artesian, of Cucamonga quadrangle .... Pocket.
  of Pasadena quadrangle .... Pocket.
  of Pomona quadrangle .... Pocket.
  of southern California Valley .... Pocket.
Maps, irrigation, of Cucamonga quadrangle .... Pocket.
  of Pasadena quadrangle .... Pocket.
  of Pomona quadrangle .... Pocket.
Marengo Water Co., irrigation plant of .. 121-122
Martin cienaga, location and character of... 35
  water of 81-82
Massey, F. H., well of, fluctuations in 61
Millard Canyon, waters of 117-118
Monk Hill, character of 50, 51
Monrovia Water Co., irrigation plant of.... 114
Montebello Land and Water Co., irrigation plant of 122
Mountains, age of 17-18
  origin of 14-15, 16
  rainfall in 19
Mountain View Water Co., irrigation plant of 86
  wells of 144
Mud Springs cienaga, water of 93

N.

Neff, records of 54
New Deal Land and Water Co., irrigation plant of 96
North Pasadena basin, wells of 51
North Pasadena Land and Water Co., irrigation plant of 122-124

O.

Oil, relation of, to fault lines 16
Old Settlers Water Co., irrigation plant of.. 74
Ontario colony, irrigation in 75-78
Ontario Water Co., irrigation plant of. 75, 76, 79-80
  wells of 150
Orange Avenue Land and Water Co., irrigation plant of 109
Orange Grove Water Co., irrigation plant of 87-88

P.

Palomares, Ignacio, water rights of 80
Palomares cienaga, explanation of 38-39, 42
  panoramic view of 8
  waters of 39, 56
Palomares Irrigation Co., irrigation plant of 83
  wells of 151
Pasadena, rainfall at 20, 21
Pasadena basin, underground waters of.... 50-54
  wells of 51, 53
    fluctuations in 65-66
Pasadena Lake Vineyard Land and Water Co., irrigation plant of 124-130
  well of 51
Pasadena Land and Water Co., irrigation plant of 125, 130-135
  well of 53
Pasadena quadrangle, artesian map of.. Pocket.
  irrigation in 139
  irrigation map of .... Pocket.
  wells in, data on 160-175

Paso de Bartolo, description of 48
  springs near 47
  wells at 166, 168-169, 173
Percolation, factors of 26-28
Peyton well, description of 45
  section of, figure showing 45
Physiography, outline of 13-18
Pipe lines, location of, maps showing.... Pocket.
Pomona, irrigation at 80-84
  rainfall at 20, 21
  water supply of 84
  wells near 32, 42
    fluctuations in 56-58, 62-64
Pomona Land and Water Co., litigation of 77
Pomona quadrangle, artesian map of ... Pocket.
  irrigation in 139
  irrigation map of .... Pocket.
  wells in, data on 152-160
Potrero de Felipe Lugo, wells at, data on... 165-166, 173
Potrero Grande, wells at, data on 163, 165-166, 175
Precipice Canyon Water Co., irrigation plant of 117
Puente Hills, rocks of 10
Pumping plants, increasing use of 7
  location of, maps showing .... Pocket.

R.

Rainfall, distribution and amount of 18-21
  importance of 22-24
Raymond Hill, wells near 53
Raymond Hill dike, description of 31
  effects of 53
Red Hills, description of 34
  gravel of 12
  sections through, figures showing 34
  waters of 35-37
Red Hills formation. *See* Earlier alluvium.
Relief, age of 17-18
  causes of 14-15, 18
Reservoirs, surface, lack of 24
Reservoirs, underground, flow from 31-33
  origin of 14, 18, 29
  replenishment of 23-24, 28-29
Riverside, rainfall at 19
Riverside Vineyard Association, well of.... 140
Rock floor, character of 31-33
Run-off, factors in 22-23

S.

San Antonio, wells at, data on 169, 172-173
San Antonio Canyon, underground waters from 37-39
  water of 80, 85
San Antonio Creek, absorption work on.... 26
San Antonio fan, growth of 42
San Antonio Water Co., irrigation plant of 75-78, 80
  litigation of 72-73
  wells of 143-144, 149
    section of, figure showing 36
San Bernardino, rainfall at 19, 21
San Bernardino basin, depth of 33
  study of 8
  underground water in, fluctuations in.. 55
San Bernardino Range, physiography of... 17-18
San Dimas, irrigation near 93-96

Page
San Dimas, wells near 96
  fluctuations in 58-60
San Dimas Canyon, flow from 93-95
San Dimas district, gravel in, depth of 45-46
  location of 43
  surface conditions in 43-45
  underground water in 45-47
    development of 43
San Dimas Irrigation Co., irrigation plant of 93-95
San Dimas Land and Water Co., history of 93-94
San Dimas Wash, description of 43
  section across, figure showing 47
  underground water of 95
  wells in 107-108
Sands, absorptive capacity of 26-28
San Francisquito, wells at, data on 164-167, 175
San Gabriel Canyon, underflow of 102
San Gabriel Orange Grove Association, irrigation plant of 125-126, 131
San Gabriel Power Co., history of 111
San Gabriel Range, physiography of 17-18
  rocks of 10
  section of, figure showing 38
San Gabriel River, description of 9
  flow of 24, 98-101, 111
San Gabriel Valley, absorption in 28-29
  depth of 32-33
  description of 9, 13-14, 48-49
  gravel of, depth of 49
  irrigation in 28
  irrigation systems of 97-106
  underground water of 47-50
  wells in, fluctuations of 64-65
San Jose, wells at and near, data on 147-149, 151-153, 156-160
San Jose Creek, description of 42, 55
San Jose Ranch Co., history of 93
San Jose Valley, irrigation plants in 90-91
  underground water of 42, 55
  wells in 42
San Gabriel Wash, description of 9
San Pasqual, wells at, data on 161-162, 168, 173-175
San Pasqual Wash, wells on 121
San Rafael, wells at, data on 169-171, 173
San Rafael Hills, rocks of 10
Santa Ana River, flow of 40
Santa Ana Wash, absorption work in 25-26
Santa Anita, irrigation near 116
  wells at, data on 160-163, 167-168, 174-175
Santa Anita Canyon, water of 115
Santa Anita Co., irrigation plant of 114-115
Santa Monica Mountains, rocks of 10
Sawpit Canyon, waters of 114-115
Seasons, character of 18
  relation of, to well fluctuations 54-67
Sedimentary rocks, water in 10-11
Sexton Bros., well of 140
Sheep Corral, developments at 130-131, 132
  springs at 52
Sierra Madre Water Co., irrigation plant of 115, 116

Page
Slichter, C. S., on percolation through sand 26-27
  on underflow 29
Soils, character of, relation of, to percolation 28
Southern California, valley of. *See* Valley of Southern California.
Spadra, wells near 42
Sparks, U. L., well of 45
Storage, facilities for 24
Storage, underground. *See* Reservoirs, underground.
Streams, run-off in 22-23
Sunny Slope, wells at 65, 118-119
Sunny Slope Water Co., irrigation plant of 118-119
Sunset Water Co., irrigation plant of 74-75
  wells of 142
  wells of, section of, figure showing 39

T.

Tables, comment on 138-139
Temperature, relation of to rainfall 19
Titus ranch, well on 65
Topography, outline of 13-18

U.

Underflow, permanence of 23-24
  source of 25
  See also Reservoirs, underground.
Upland, irrigation near 87
Upland Water Co., irrigation plant of 87
  well of 142

V.

Valley fill, depth of 33
  origin of 30
Valley of Southern California, artesian map of Pocket.
  definition of 13
  subdivisions of 13-14
Valleys, age of 17-18
  origin of 14-15, 16, 29
Verdugo Canyon, waters of 135-136
Verdugo Canyon Water Co., irrigation plant of 135-137
Verdugo Mountains, rocks of 10
Vineland, wells near, fluctuations in 60-61
Vineland irrigation district, irrigation plants of 110
Waters, absorption of 25-26
  conservation of 25-26
Water supplies, dependence of, on rainfall 22-24
Wells, data on 140-175
  depths of 31-32
  location of, maps showing Pocket.
  water level in, fluctuations of 54-67
    maps showing Pocket.
Wells, flowing, yield of 137-138
Western Water and Power Co., irrigation plant of 107-108
  well of, section of, figure showing 46
White, W. U., work of 67, 139
Woyden, well near, description of 31-32, 49
  well near, record of, figure showing 32
Wright, E. T., aid of 67

O

PER NO. 219 PL. III

R.2 E. 116°45'

San I
fl
San I
San I
lo
st
us

San D
San D
San D
se
un
we
Sands,
San F
San G
San G

San G
San G
roc
sec
San Ga
flo
San Ga
dep
des
gra
irri
irri
und
well
San Jos

San Jos
San Jos
San Jos
und
well
San Gab
San Pas
San Pas
San Raf
San Raf
Santa A
Santa A
Santa A
wells
Santa Ar
Santa Ar
Santa M
Sawpit C
Seasons,
relati
Sediment
Sexton B
Sheep Co
spring
Sierra M

7

San 1
fl
San 1
San 1
le
si
u

San D
San D
San D
se
ur
w
Sands
San F
San G
San G.

San G
San G
ro
sec
San G
flo
San G
deg
des
gra
irri
irri
unc
wel
San Jo

San Jos
San Jos
San Jos
und
well
San Gal
San Pas
San Pas
San Raf
San Raf
Santa A
Santa A
Santa A
well
Santa A
Santa A
Santa M
Sawpit C
Seasons
relat
Sedimen
Sexton E
Sheep Co
sprin
Sierra M

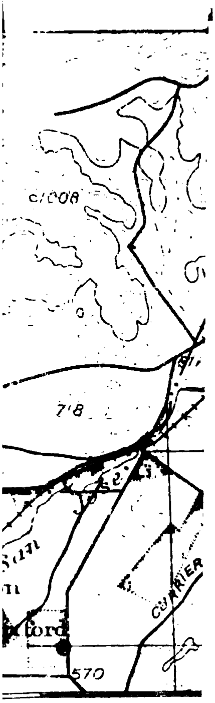
San
a
San
San
k
s
u

San L
San L
San L
se
u
w
Sands
San F
San G
San G

San G
San G
ro
sec
San G
flo
San G
de
de
gr
irri
irri
un
we
San Jo

San Jo
San Jo
San Jo
und
well
San Ga
San Pa
San Pa
San Ra
San Ra
Santa
Santa
Santa
wel
Santa
Santa
Santa
Sawpit
Season
rel
Sedim
Sexton
Sheep
sp
Sierra

7



LINES, A

CALIFOR

ENHALL, 1904

3

5 kilometer

7

7

7

U.S. Geological Survey

Water Supply Paper
Vols. 214-219

DATE DUE	BORROWER'S NAME

3 2044 102 944 592